Lloyd's Register

Rules and Regulations for the Classification of Naval Ships, January 2011

Notice No. 2

Effective Date of Latest Amendments:

See page 1

Issue date: November 2011

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF NAVAL SHIPS, *January 2011*

Notice No. 2

This Notice contains amendments within the following Sections of the *Rules and Regulations for the Classification of Naval Ships, January 2011.* The amendments are effective on the dates shown:

Volume	***Part***	***Chapter***	***Section***	***Effective date***
1	1	2	1, 2, 3	1 January 2012
1	1	3	2	1 January 2012
1	3	5	8	1 January 2012
2	1	2	3	Corrigendum
2	1	2	4, 5, 13	1 January 2012
2	1	3	1, 2	1 January 2012
2	1	4	1	1 January 2012
2	2	1	2, 6, 7, 9, 11, 15	1 January 2012
2	2	2	7	1 January 2012
2	4	1	7	1 January 2012
2	4	2	Whole Chapter	1 January 2012
2	4	4	1, 2, 7, 8	1 January 2012
2	6	1	8	1 January 2012
2	7	1	5, 11	1 January 2012
2	7	2	1, 10	1 January 2012
2	7	3	1, 2, 3, 4, 8	1 January 2012
2	7	4	2	1 January 2012
2	7	5	11	1 January 2012
2	8	1	18	1 January 2012
2	9	1	1, 2, 6	1 January 2012
2	10	1	1, 6 to 21	1 January 2012
2	11	1	2	1 January 2012
2	11	2	2, 3	1 January 2012
3	2	3	3	Corrigendum
3	3	1	1	1 January 2012

It will be noted that the amendments also include corrigenda, which are effective from the date of this Notice.

The *Rules and Regulations for the Classification of Naval Ships, January 2011* are to be read in conjunction with this Notice No. 2. The status of the Rules is now:

Rules for Naval Ships	Effective date:	January 2011
Notice No. 1	Effective date:	1 January 2011 & Corrigenda
Notice No. 2	Effective date:	1 January 2012 & Corrigenda

Volume 1, Part 1, Chapter 2

Classification Regulations

Effective date 1 January 2012

■ *Section 1*

Conditions for Classification

1.1 Framework of Classification

~~*1.1.11* It is a requirement of classification that lifting appliance arrangements are to comply with and be maintained in compliance with specified standard(s). The specified standard(s) and ongoing certification regime are to be notified to LR by the Naval Authority in writing. LR will provide advice on this aspect at the request of the Owner/Naval Authority, *see also* 3.9 for the **LAP** or **LA** notation.~~

1.1.11 It is a requirement that where a vessel operates aircraft, it is classed in accordance with the requirements of the AIR notation defined in Pt 4, Ch 2,10 for the landing, manoeuvring and parking areas.

1.1.12 It is a requirement that, where the vessel has fitted on board lifting appliances which are considered by LR to be essential for it to fulfil its primary operational role (e.g., aircraft lifts on aircraft carriers, landing platform dock stern ramp) and that there are no alternative means of operation, that it is classed in accordance with the requirements of the **LA** notation. The lifting appliance(s) are to be designed, built and surveyed in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (LAME).

Existing paragraphs 1.1.12 *and* 1.1.13 *have been renumbered* 1.1.13 *and* 1.1.14*.*

■ *Section 2*

Scope of the Rules

2.2 Definitions

~~*2.2.10* **Operational envelope**. The operational envelope defines the ship's service in terms of operational speeds, wave heights, displacements, service area, temperatures, motions, flight deck operations and radar, and is to be provided by the Owner.~~

2.2.10 **Operational envelope**. The operational envelope will be provided by Lloyd's Register as an Annex to the Classification Certificate and defines limits of the vessel's service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge where this is required.

2.2.14 **Concept of operations**. The concept of operations provides information with regard to the ship's service in terms of purpose and function (including crewing), operational speeds, wave heights, displacements; service area, temperatures, motions, flight deck operations; normal and emergency arrangements and other information pertinent to the design of the ship and is to be provided by the Owner.

■ *Section 3*

Character of Classification and Class notations

3.4 Ship type notations

3.4.6 **NS3** vessels

(a) For vessels being built to the **NS3** notation, the following shall apply where the vessel is also being designed and built to comply with appropriate statutory regulations for the intended service of the vessel.

(b) LR is to be contracted to issue Statements of Compliance with the nominated statutory regulation. Appropriate statutory regulations may include, but are not limited to:
   (i) International Convention for the Safety of Life at Sea.
   (ii) Code of Safety for Special Purpose Ships (SPS Code).
   (iii) UK MCA Small Commercial Vessel and Pilot Boat (SCV) Code or similar recognised regulation or National Standard.

(c) Vessels are to be certified for Intact and Damaged Stability, and Carriage of Munitions by a recognised Organisation. Other statutory requirements such as compliance with the International Convention for the Prevention of Pollution from Ships should also be issued by a recognised Organisation.

(d) Details of required certification are to be submitted to LR at the time of contracting. Form 2506 is to be used for this information.

(e) Where a vessel is so contracted, the following aspects of the *Rules and Regulations for the Classification of Naval Ships* will be exempted for the requirements of Classification:
All requirements for a Naval Authority to agree the contents of:
   (i) Concept of Operations Document(s).
   (ii) Design Statements.
   (iii) Other aspects as wherever referred to in the Rules are not applicable.

(f) The requirements of Vol 1, Pt 5, Ch 4,6.1.4 are to be complied with.

(g) The limits of the Operating Envelope to which the hull structure has been approved are to be displayed prominently in the wheelhouse.

(h) Where a vessel is to be classed using this approach, any exemptions are to be agreed by the Naval Authority and justified by using the approach set out in Vol 2, Pt 1, Ch 5, Requirements for Machinery and Engineering Systems of Unconventional Design.

3.9 Other notations

~~*3.9.1* **Mandatory operational notation.**~~

~~**AIR**~~ ~~Mandatory notation for ships that operate aircraft in accordance with the requirements of Pt 4, Ch 2,10 for the landing, manoeuvring and parking areas.~~

~~*3.9.2* **LA**. This special feature Class notation is mandatory where the vessel has fitted on board lifting appliances which are considered by LR to be essential for it to fulfil its primary operational role (e.g. Aircraft lifts on aircraft carriers, Landing platform dock stern ramp) and that there are no alternative means of operation. The lifting appliance is to be designed, built and surveyed in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (LAME).~~

Existing paragraphs 3.9.3 to 3.9.23 *have been renumbered* 3.9.1 *to* 3.9.21.

Volume 1, Part, 1, Chapter 3

Periodical Survey Regulations

Effective date 1 January 2012

■ *Section 2*

Annual Surveys – Hull, machinery and optional requirements

2.3 Machinery

2.3.14 For ships fitted with an electronically controlled engine for main propulsion, essential auxiliary ~~and~~ or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) ~~A general examination of the electronic control system and associated parts.~~ Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load.

~~(b) Verification of evidence of satisfactory operation of the engine and where possible this is to include a running test under load.~~

~~(c)~~ (b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.

~~(d) Verification that any changes to hardware and software for control of the engine have been submitted and approved by LR.~~

~~(e) Verification that any changes to control and monitoring arrangements that affect the operation of the engine have been submitted and approved by LR.~~

~~(f) Verification that where changes have been carried out, there is evidence of acceptance tests and trials for Programmable Electronic Systems which include confirmation of software life cycle activities appropriate to the stage in the system's life cycle at the time of system examination.~~

~~(g) Identification and verification that the key monitoring parameters/sensors are in working order.~~

(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

Volume 1, Part 3, Chapter 5

Anchoring, Mooring, Towing, Berthing, Launching, Recovery and Docking

Effective date 1 January 2012

■ *Section 8*

Windlass and capstan design and testing

8.3 Control arrangments

8.3.10 Control systems for windlasses are to comply with the requirements of Vol 2, Pt 9, Ch 1,2.

8.3.11 Windlass motors are to be protected against overload, overspeed and overpressure, using appropriate safety techniques suitable for the intended installation.

8.5 Protection arrangements

8.5.4 For arrangements of power transmission systems and relief requirements, *see* Vol 2, Pt 7, Ch 5,11.1.2.

Volume 2, Part 1, Chapter 2

Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems

CORRIGENDUM

■ *Section 3*

Particulars to be submitted

3.3 Calculations and specifications

3.3.16 **Schedule of testing and trials**. Schedules of testing machinery at the manufacturers, pre-sea trial commissioning and sea trials are to be submitted to LR and agreed before commencement of testing and trials. The testing and trials schedules are to identify all modes of ship and machinery operation and the sea trials are to include typical port manoeuvres under all intended operating modes. Reference is also made to the following Rules:

- Vol 1, Pt 3, Ch 5, Section 8 – Windlass and capstan trials
- Vol 2, Pt 1, Ch 2, Section 15 – Steering systems
- Vol 2, Pt 1, Ch 2, Section 16 – Sea trials
- Vol 2, Pt 10, Ch 1, Section ~~20~~ 21 – ~~Electrical~~ Testing and trials
- Vol 2, Pt 9, Ch 1, Section 6 – Control engineering trials

Testing and trials are to be witnessed by an LR Surveyor unless an alternative arrangement is agreed in writing prior to the trials by the Surveyor. Reports of testing and trials are to be submitted to an LR Surveyor after completion.

Effective date 1 January 2012

■ *Section 4*

Operating conditions

4.4 Ambient reference conditions

4.4.1 The rating for classification purposes of main and essential auxiliary machinery intended for installation in naval sea-going ships to be classed for unrestricted (geographical) service is to be based on:

- A total barometric pressure of 1000 mb.
- An engine room ambient temperature or suction air temperature of 45°C.
- A relative humidity of 60 per cent.
- Sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32°C.

NOTE
The ~~engine~~ manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

■ *Section 5*

Machinery space arrangements

5.6 Resin chocks

5.6.3 Materials for chocking are to be approved for the maximum ambient operating temperature of the space in which they are installed.

~~5.6.3~~ 5.6.4 Where the Naval Authority has defined military requirements that include design and installation of machinery to withstand shock, the resin is to be approved for this application.

■ *Section 13*

Water jet units

13.1 Design

13.1.1 For details of design requirements, *see* Pt 4, ~~Ch 3~~ Ch 2.

13.3 Testing

~~*13.3.2* Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent standard.~~

Volume 2, Part 1, Chapter 3

Requirements for Fusion Welding of Pressure Vessels and Piping

Effective date 1 January 2012

Section 1

General

1.1 Scope

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. ~~The~~ For Class 1, 2/1 and 2/2 pressure vessels, the manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships*, Book A Procedure MQPS 0-4.

Section 2

Manufacture and workmanship of fusion welded pressure vessels

2.3 Tolerances for cylindrical shells

Table 3.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel, in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300	1,0 per cent of internal diameter	1,2 mm
> 300 ≤ 460		1,6 mm
> 460 ≤ 600		2,4 mm
> 600 ≤ 900		3,2 mm
> 900 ≤ ~~1200~~1220		4,0 mm
> 1220 ≤ 1520		4,8 mm
> 1520 ≤ 1900		5,6 mm
> 1900 ≤ 2300	19 mm	6,4 mm
> 2300 ≤ 2670		7,2 mm
> 2670 ≤ 3950		8,0 mm
> 3950 ≤ 4650	19 mm	0,2 per cent of internal diameter
> 4650	0,4 per cent of internal diameter	

Volume 2, Part 1, Chapter 4

Spare Gear for Machinery Installations

Effective date 1 January 2011

Section 1

General

~~1.2 Tables of spare parts~~

~~*1.2.1* For general guidance purposes spare parts for main and auxiliary machinery installations are shown in the following Tables:~~

~~Table 4.1.1 Spare parts for main oil engines.~~
~~Table 4.1.2 Spare parts for auxiliary oil engines.~~
~~Table 4.1.3 Spare parts for main steam turbines.~~
~~Table 4.1.4 Spare parts for auxiliary steam turbines.~~
~~Table 4.1.5 Spare parts for auxiliary air compressors.~~
~~Table 4.1.6 Spare parts for boilers supplying steam for propulsion and for essential services.~~
~~Table 4.1.7 Spare parts for gas turbines.~~

1.2 Guidance for spare parts

1.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct Live.

~~**Table 4.1.1**~~ ~~**Spare parts for main oil engines**~~ ~~*(see continuation)*~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1	–
Main thrust block	Pads for one face of Michell type thrust block or Inner and outer race with rollers where roller thrust bearings are fitted	1 set 1	1 set 1
Cylinder liner	Cylinder liner complete with joint rings and gaskets	1	–
Cylinder cover	Cylinder cover, complete with valves, joint rings and gaskets. For engines without covers, the respective valves for one cylinder unit	1	–
	Cylinder cover studs or bolts, with nuts, as applicable for one cylinder	$^{1}/_{2}$ set	–
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets	1 set
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set	1set
	Starting air valve, complete with casing, seat, springs and other fittings	1	1
	Relief valve, complete	1	1
	Fuel injection valves of each size and type fitted, complete with all fittings, for one engine *NOTE. Engines with three or more fuel injection valves per cylinder: two fuel injection valves complete per cylinder and a sufficient number of valve parts, excluding the body, to provide, with those fitted, a full engine set	1 set*	$^{1}/_{4}$ set
Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set	–
	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set	–
Pistons	Crosshead type, piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1	–
	Trunk piston type, piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod	1	–
Piston rings	Piston rings, for one cylinder	1 set	–
Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set	–

~~**Table 4.1.1 Spare parts for main oil engines** *(conclusion)*~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Gear and chain for camshaft drives	Chain drive: separate links with pins and rollers of each size and type fitted	6	—
	Bearing bushes of each type fitted	1 set	—
Cylinder lubricators	Lubricator complete, of the largest size, with its chain drive or gear wheels	1	—
Fuel injection pumps	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)	1	—
Fuel injection piping	High pressure fuel pipe of each size and shape fitted, complete with couplings	1	—
Scavenge blowers (including turbo-chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if of other types NOTE The spare parts may be omitted where it has been demonstrated at the Enginebuilder's Works, or during sea trials, for an engine of the type concerned, that the engine can be manoeuvred satisfactorily with one blower out of action. The requisite blanking and/or blocking arrangements, applicable for running with one blower out of action as demonstrated, are to be available on board	1 set	—
Scavenging system	Suction and delivery valves for one pump of each type fitted	1 set	—
Reduction and/or reverse gear	Complete bearing bush, of each size fitted in the gearcase assembly	1 set	—
	Roller or ball race, of each size fitted in the gearcase assembly	1 set	—
Main engine-driven air compressors	Piston rings of each size fitted	1 set	—
	Suction and delivery valves complete of each size fitted	$^1/_2$ set	
Gaskets and packings	Special gaskets and packings of each size and type fitted for cylinder covers and cylinder liners for one cylinder	1 set	—

~~Table 4.1.2 Spare parts for auxiliary oil engines~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Main bearing or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1	–
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets	–
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set	–
	Starting air valve, complete with casing, seat, springs and other fittings	1	–
	Relief valve, complete	1	–
	Fuel injection valves of each size and type fitted, complete with all fittings, for one engine	$^1/_2$ set	–
Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set	–
	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set	–
	Trunk piston type: gudgeon pin with bush for one cylinder	1 set	–
Piston rings	Piston rings, for one cylinder	1 set	–
Piston cooling	Piston cooling fittings, for one cylinder unit	1 set	–
Fuel injection pumps	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.)	1	–
Fuel injection piping	High pressure fuel pipe of each size and shape fitted, complete with couplings	1	–
Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	1 set	–

~~Table 4.1.3 Spare parts for main steam turbines~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine	1	–
Turbine thrust	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size for one engine Assorted liners for one block where fitted	1 set	1 set
Main thrust block	Pads for one face of Michell type thrust block	1 set	1 set
	or		
	Inner and outer race with rollers where roller thrust bearings are fitted	1	1
Turbine shaft sealing rings	Carbon sealing rings, where fitted, with springs, for each size and type of gland, for one engine	1 set	–
Oil filters	Disposable filter elements of each type and size fitted	1 set	–

~~**Table 4.1.4 Spare parts for auxiliary steam turbines**~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine	1	–
Turbine thrust	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size for one engine Assorted liners for one block where fitted	1 set	1 set
Turbine shaft sealing rings	Carbon sealing rings, where fitted, with springs, for each size and type of gland, for one engine	1 set	–
Oil filters	Disposable filter elements of each type and size fitted	1 set	–

~~**Table 4.1.5 Spare parts for auxiliary air compressors**~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Piston rings	Rings, of each size fitted, for one piston	1 set	1 set
Valves	Suction and delivery valves, complete, of each size fitted	1/2 set	1/2 set

~~**Table 4.1.6 Spare parts for boilers supplying steam propulsion and for essential services**~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Tube stoppers or plugs	Tube stoppers or plugs, of each size used, for boiler, superheater and economiser tubes	10	6
Oil fuel burners	Oil fuel burners complete or a complete set of wearing parts for the burners, for one boiler	1 set	1 set
Gauge glasses	Gauge glasses of round type	2 sets per boiler	2 sets per boiler
	Gauge glasses of flat type	1 set for every two boilers	1 set for every two boilers

~~**Table 4.1.7 Spare parts for gas turbines**~~

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Reduction gear	Complete bearing bush of each size fitted for the pinion(s) and gear wheel shaft for one turbine	1	–
Oil fuel burners	Oil fuel burners complete or a complete set of wearing parts for the burners, for one turbine	1 set	1 set
Igniters	Full set for one turbine	1 set	1 set
Oil filters	Disposable filter elements of each size and type fitted	1 set	1 set
Oil fuel metering	Fuel metering unit complete	1 set	–
Gas turbine manufacturer's recommended spares for each installation in addition to the above		1 set	1 set

Volume 2, Part 2, Chapter 1

Diesel Engines

Effective date 1 January 2012

■ *Section 2*
Particulars to be submitted

2.1 Plans and information

(*Part only shown*)

2.1.1 At least three copies of the following plans are to be submitted for consideration:

- ~~The specification for a mass produced engine including manufacturing processes and quality control procedures, see 11.1.4 and 11.2.3~~
- Additionally, for mass produced engines:
  - (a) For consideration of an engine type to be approved:
    - (i) Engine specification, *see* 11.1.4.
    - (ii) Manufacturing processes and quality control information, *see* 11.2.3.
    - (iii) List of sub-contractors for main parts.
    - (iv) Procedures for configuring during commissioning.
  - (b) For engines of an approved type to be installed on a ship, a compliance and inspection certificate, *see* 11.4.
- For engine control, alarm, monitoring and safety systems, the plans and information required by Pt 9, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 15.2.

~~*2.1.5*~~ *2.1.4* A Failure Mode and Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

It is not necessary to consider failure modes relating to the engine components.

~~*2.1.6*~~ *2.1.5* Plans and details for dead ship condition starting arrangements are to be submitted for appraisal, *see* 7.1.

~~*2.1.4*~~ *2.1.6* For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee's works.

~~*2.1.7* Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of an electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criteria of the engine. This is concerned with the functioning of the control system and not failure of the software itself.~~

~~*2.1.8*~~ *2.1.7* Where considered necessary additional documentation may be required.

■ *Section 6*
Safety arrangements on engines

6.5 Crankcase access and lighting

~~6.5.2 Interior lighting, where fitted, is to be flameproof.~~

6.5.2 When interior lighting is provided it is to be flameproof (Ex 'd') in relation to the interior and details are to be submitted for approval, *see also* Pt 10, Ch 1,13. No wiring is to be fitted inside the crankcase.

■ *Section 7*
~~Starting arrangements~~
Air compressors and starting arrangements

Existing sub-Section 7.1 *has been renumbered* 7.11.

~~7.2 Starting arrangements – Air compressors~~

7.1 General requirements

7.1.1 The requirements of this Section are applicable to reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services.

~~7.2.1~~ *7.1.2* Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

~~7.2.2~~ *7.1.3* The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

~~7.2.3~~ *7.1.4* Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

~~7.2.4~~ *7.1.5* Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shut-down.

~~7.2.5~~ *7.1.6* Where starting air is provided from a general use compressed air system, it is to be demonstrated that the system capacities are consistent with the philosophy described in 7.2.1.

7.2 Plans and particulars

7.2.1 Detailed plans, particulars, dimensional drawings and material specifications for compressor crankshafts are to be submitted in triplicate. Plans and particulars for other parts and calculations, where applicable, are to be submitted to LR upon request.

7.2.2 Where compressors of a special type or design are proposed, the requirements of Pt 7, Ch 15 of the *Rules and Regulations of the Classification of Ships* are to be applied.

7.3 Materials

7.3.1 The specified minimum tensile strength of castings and forgings for compressor crankshafts are to be within the limits given in 3.2.1 and for grey cast iron to be not less than 300 N/mm^2.

7.3.2 Where it is proposed to use materials outside the ranges specified in 7.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

7.3.3 Materials for components are to be tested as indicated in 3.1.

7.3.4 For crankshafts with a calculated crank pin diameter equal to or greater than 50 mm, they are to be manufactured and tested in accordance with the requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials*. For calculated crank pin diameters less than 50 mm, a manufacturer's certificate may be accepted, *see* Ch 1,3.1.3(c) of the Rules for Materials.

7.4 Design and construction

7.4.1 A fully documented fatigue strength analysis is to be submitted, indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue strength criterion. Alternatively, the requirements of 7.4.2 to 7.4.6 may be used.

7.4.2 The diameter, *dp*, of a compressor crankshaft is to be not less than *d*, determined by the following formula, when all cranks on the shaft are located between two main bearings only:

$$d = V_c \left(\frac{D^2 p Z}{78{,}5} \left(\frac{S}{16} + \frac{a b}{a + b} \right) \right)^{1/3} \text{ mm}$$

where

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a + b$ = span between inner edges of main bearings, in mm

d_p = proposed minimum diameter of crankshaft, in mm

p = design pressure, in bar g, as defined in Pt 7, Ch 1,3.3.1
D = diameter of cylinder, in mm
S = length of stroke, in mm
V_c = 1,0 for shafts having one cylinder per crank, or

$$\left.\begin{array}{l} = 1{,}05 \text{ for } 90^\circ \\ = 1{,}18 \text{ for } 60^\circ \\ = 1{,}25 \text{ for } 45^\circ \end{array}\right\} \text{between adjacent cylinders on the same crankpin}$$

for the shaft and cylinder arrangements as detailed in Table 1.7.1

$$Z = \frac{560}{\sigma_u + 160} \quad \text{for steel}$$

$$Z = \frac{700}{\sigma_u + 260 - 0{,}059 d_p} \quad \text{for spheroidal or nodular graphite cast iron}$$

$$Z = \frac{700}{\sigma_u + 260 - 0{,}069 d_p} \quad \text{for grey cast iron}$$

σ_u = specified minimum tensile strength of crankshaft material, in N/mm^2.

Table 1.7.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	—
4	2	45	60	—
1	3	45	60	90
2	3	45	60	—
3	3	45	—	—
1	4	45	60	—
2	4	45	—	—

7.4.3 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

7.4.4 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

$0{,}4d^3$ for the web adjacent to the bearing
$0{,}75d^3$ for intermediate webs

where
B = breadth of web, in mm
d = minimum diameter of crankshaft as required by 7.4.2, in mm
t = axial thickness of web, which is to be not less than $0{,}45d$ for the web adjacent to the bearing, or $0{,}60d$ for intermediate webs, in mm.

7.4.5 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than $0{,}05d$. Smaller fillets, but of a radius not less than $0{,}025d$, may be used, provided the diameter of the crankpin or journal is not less than cd:

where
$c = 1{,}1 - 2\dfrac{r}{d}$ but to be taken as not less than 1,0
d = minimum diameter of crankshaft as required by 8.4.2, in mm
r = fillet radius, in mm.

7.4.6 Fillets and oil holes are to be rounded to an even contour and smooth finish.

7.4.7 An oil level sight glass or oil level indicator is to be fitted to the crankcase.

7.4.8 The crankcases of compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system.

7.4.9 Compressors with shaft power exceeding 500 kW are to have torsional vibration analysis determined in accordance with Pt 5, Ch 1 as applicable.

7.4.10 The cooler dimensions for sea-water cooled stage air coolers are to be based on an inlet temperature of not less than 32°C. Where fresh water cooling is used, the cooling water inlet temperature is not to be greater than 40°C.

7.4.11 The cooler dimensions for air cooled stage air coolers are to be based on an air temperature of not less than 45°C.

7.4.12 The piping to and from the air compressor is to be arranged to prevent condensation from entering the cylinders.

7.5 Testing

7.5.1 Cylinders and liners of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

7.5.2 The compressed air chambers of the intercoolers and after coolers of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

7.6 Safety arrangements and monitoring

7.6.1 Air compressors are to be arranged and located so as to minimise the intake of air contaminated by oil or water.

7.6.2 Where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a safety valve and a pressure gauge.

7.6.3 After the final stage, all air compressors are to be equipped with a water trap and after cooler. The water traps, after coolers and the compressed air spaces between the stages are to be provided with discharge devices at their lowest points.

7.6.4 Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

7.7 Crankcase relief valves

7.7.1 In compressors having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, crankcase relief valves may be omitted.

7.7.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

7.7.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

7.7.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion.

7.7.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied. The manual is to contain the following information:

(a) Description of valve with details of function and design limits;
(b) Copy of type test certification;
(c) Installation instructions;
(d) Maintenance and in-service instructions to include testing and renewal of any sealing arrangements;
(e) Actions required after a crankcase explosion.

7.7.6 A copy of the installation and maintenance manual required by 7.7.3 is to be provided on board the ship.

7.7.7 Plans showing details and arrangements of the crankcase relief valves are to be submitted for approval, *see* 2.1.

7.7.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer;
(b) Designation and size;
(c) Month/Year of manufacture;
(d) Approved installation orientation.

7.8 Number of crankcase relief valves

7.8.1 In compressors having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; where more than one relief valve is required, the valves are to be located at or near the ends of the crankcase.

7.8.2 In compressors having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For compressors having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

7.8.3 In compressors having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crank throw.

7.8.4 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases, when the gross volume of such spaces exceeds 0,6 m^3.

7.9 Size of crankcase relief valves

7.9.1 The combined free area of the crankcase relief valves fitted on a compressor is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

7.9.2 The free area of each relief valve is to be not less than 45 cm^2.

7.9.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

7.9.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

7.10 Vent pipes

7.10.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion.

~~7.1~~ 7.11 Dead ship condition starting arrangements

Existing paragraphs 7.1.1 *to* 7.1.4 *have been renumbered* 7.11.1 *to* 7.11.4.

~~7.3~~ 7.12 Air receivers

Existing paragraphs 7.3.1 *to* 7.3.5 *have been renumbered* 7.12.1 *to* 7.12.5.

~~7.4~~ 7.13 Starting air pipe systems and safety fittings

Existing paragraphs 7.4.1 *to* 7.4.8 *have been renumbered* 7.13.1 *to* 7.13.8.

~~7.5~~ 7.14 Electrical starting arrangements

Existing paragraphs 7.5.1 *to* 7.5.3 *have been renumbered* 7.14.1 *to* 7.14.3*.*

~~7.5.4~~ 7.14.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines, as defined in 7.5.1 and 7.5.3.

Existing paragraphs 7.5.5 *to* 7.5.7 *have been renumbered* 7.14.5 *to* 7.14.7*.*

~~7.6~~ 7.15 Starting of the emergency source of power

Existing paragraphs 7.6.1 *to* 7.6.6 *have been renumbered* 7.15.1 *to* 7.15.6*.*

~~*7.6.7* Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements.~~

7.15.7 Electric starting arrangements are to also satisfy 7.14.2 to 7.14.5.

7.16 Engine control, alarm, monitoring and safety system power supplies

7.16.1 Power supplies are to be arranged so that power for electrically powered control, alarm, monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each individual source of stored energy.

7.16.2 Where adequate battery and charging capacity exists, an engine-starting battery may be used as one source of electrical power required by 8.6.1.

7.16.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 9*
Control and monitoring

9.7 Diesel engines for propulsion purposes

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):
(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.
(e) Oil fuel supply, where oil fuel grades require heating or cooling only, *see also* 9.7.5.

9.7.5 Where the oil fuel supply is heated, automatic control for viscosity may be fitted in lieu of the temperature control required by 9.7.4.

Existing paragraphs 9.7.5 *to* 9.7.7 *have been renumbered* 9.7.6 *to* 9.7.8*.*

Table 1.9.1(a) Diesel engines for propulsion purposes: Alarms and slow-downs (*Part only shown*)

Item	Alarm	Note
Electrical starting battery charge level*	Low	~~–~~ Electric start engines, *see also* 7.5.5

Table 1.9.2 Auxiliary diesel engines: Alarms and shut-downs (*Part only shown*)

Item	Alarm	Note
Electrical starting battery charge level	Low	~~–~~ Electric start engines, *see also* 7.5.5

■ *Section 11*
Mass produced engines

11.2 Procedure for approval of mass produced engines

~~*11.2.2* For the approval of a mass produced engine type, the manufacturer is to submit, in addition to the plans and particulars required by 2.1 a list of subcontractors for main parts.~~

11.2.2 For the approval of a mass-produced engine type, the manufacturer is to submit:
(a) The plans and particulars required by 2.1 for assessment.
(b) As necessary, information to assess compliance with Section 4.
(c) A list of subcontractors for main parts.
(d) Control, alarm, monitoring and safety system configuration procedures, *see* 11.4.2.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine including changes to the software and control, alarm, monitoring or safety systems, in the manufacturing or quality~~, in the manufacturing or~~ control processes, ~~or~~ in the selection of materials or in the list of subcontractors for main parts.

11.4 Compliance and inspection certificate

11.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm, monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

11.5 Type test conditions

11.5.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

Existing paragraphs 11.5.3 *to* 11.5.9 *have been renumbered* 11.5.4 *to* 11.5.10.

~~*11.5.10*~~ *11.5.11* For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performance~~s~~ profiles and control, alarm, monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

Existing paragraph 11.5.11 *has been renumbered* 11.5.12.

■ *Section 15*

Electronically controlled engines

15.1 Scope

15.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency, *see* 15.5, power purposes with programmable electronic systems implemented ~~and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems~~. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

~~*15.1.2* These engines may be of the slow, medium or high speed type. They generally have no direct camshaft driven fuel, air or exhaust systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the air or exhaust systems.~~

~~*15.1.3*~~ *15.1.2* The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using ~~one or more electronic control systems~~ programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

~~*15.1.4* Deviation from Rule requirements are to be submitted and will be specially considered.~~

15.1.3 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the engine packager or system integrator.

15.1.4 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

15.1.5 During the life of the engine details of any proposed changes that affect ~~to hardware, software, control and monitoring systems~~ the safe and reliable operation of the engine are to be submitted to LR for approval.

15.2 Plans and particulars

15.2.1 In addition to the plans and particulars required by Ch 1,2, the following information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure ~~or~~, degraded modes of operation, or malfunction, with particular reference to the functioning of ~~electronic control~~ programmable electronic systems and any sub-systems. Also, the information is to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that ~~can be~~ is electronically controlled ~~by electronic control systems~~.

~~(b) Details of hydraulic systems for actuation of subsystems (fuel injection, air inlet or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.~~

(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.

(c) ~~Failure Modes and Effects Analysis (FMEA)~~ A risk-based analysis of the mechanical, pressure containing ~~and~~ electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved ~~so that a system will tolerate a single failure in equipment or loss of an associated sub-system such that operation of the engine will not be lost or degraded beyond acceptable performance criteria of the engine.~~ in accordance with 15.3.

~~(d) A schedule of testing and trials to demonstrate that the engine is capable of operating as described in the design statement, and any testing required to verify the conclusions of the FMEA. The schedule is to include integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with LR for selected cases based on the FMEA required in (c).~~

(d) Details of hydraulic systems for actuation of sub-systems (fuel injection or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

~~(e) Operating manuals which describe the particulars of each system and, together with operating and maintenance instructions, to include reference to the arrangements for making modifications and changes to electronic control systems and for the functioning of sub-systems.~~

~~(f)~~ (e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.

~~(g)~~ (f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

~~(i)~~ (g) Evidence of type testing of the engine with ~~electronic controls~~ the programmable electronic system, or a proposed test plan at the ~~engine builders~~ engine packager's facility with the programmable electronic ~~controls~~ system functioning, to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic ~~control~~ system.

(h) Schedule of testing at the ~~engine builders~~ engine packager's or system integrator's facility, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
  (i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
  (ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
  (iii) testing required to verify the conclusions of the risk-based analysis.
  The scope of these tests is to be agreed with LR.

~~(k)~~ (j) For emergency engines, evidence and details showing compliance with ~~15.5~~ 15.7.

15.2.2 In addition to the applicable plans and particulars required by ~~Part 9~~ Pt 9, Ch 1,1.2.3 to 1.2.6, the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

~~(a) System requirements specification.~~
~~(b) Description of operation with explanatory diagrams.~~
~~(c) Line diagrams of control circuits.~~
~~(d) List of monitored points.~~
~~(e) List of control points.~~
~~(f) List of alarm points.~~
~~(g) List of safety functions and details of any overrides, including consequences of use.~~
~~(h) Details of hardware configuration.~~
~~(i) Hardware certification details.~~
~~(k) Software quality plan.~~
~~(l) System integration plan.~~
~~(m) Failure Mode and Effects Analysis (FMEA). *See* 2,1.5.~~
~~(n) Factory acceptance, integration, harbour and sea trials/test schedules for hardware and software.~~
~~(o) Software certification details.~~
~~(p) Quality plan for sourcing, design installation and testing of all components used in the control, alarm, monitoring and safety systems installed with the engine for engine operation.~~

(a) Engine configuration details, *see* 15.5.2.
(b) Software quality plans, including configuration management documents.
(c) Software safety evidence.
(d) Software assessment inspection report such as SCA or IEC 61508, as applicable.

15.3 Risk-based analysis

15.3.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and ship and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 15.3.2 to 15.3.4, relevant to the engine application.

15.3.2 For ships with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 9, Ch 1,2.5.7 and 2.13.2;
(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 9, Ch 1,2.14.4 and 2.14.5; and
(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see* Pt 9, Ch 1,2.3.12, 2.4.5, 2.5.4, 2.10.3, 2.10.4 and 2.14.5.

15.3.3 A risk-based analysis is to be carried out for:

(a) main engines on ships with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the ship's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall ship installation, with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the ship. Arrangements satisfying the criteria of 15.3.2(a) to (c) will also be acceptable.

15.3.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic engine system failure resulting in the loss of the ability to provide emergency power has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified and the report is to include documentation of:

(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

15.3.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.

(f) Evaluate the local effects (e.g., fuel injection failure) and the effects on the system as a whole (e.g., loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode (e.g., system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

15.3.6 In an electronically controlled engine, it is necessary to define the essential services on which the operation of the engine relies, and the control functions, alarm functions and safety functions for the equipment and machinery providing these services. Examples of essential services are:
(a) Starting arrangements.
(b) Fuel supply arrangements.
(c) Lubricating oil arrangements.
(d) Hydraulic oil arrangements.
(e) Cooling arrangements.
(f) Power supply arrangements.

15.3.7 Where emergency engines are used as harbour sets, the system is to comply with the requirements of Pt 10, Ch 1,3.2.6. This function is to be included in the risk-based analysis.

15.3.8 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

~~15.3~~ 15.4 Oil fuel and hydraulic oil systems

Existing paragraphs 15.3.1 *to* 15.3.12 *have been renumbered* 15.4.1 *to* 15.4.12.

~~15.4 Electronic control systems~~

~~*15.4.1* Plans and details of electronic control systems are to comply with Parts 9 and 10 as applicable.~~

~~*15.4.2* Programmable electronic equipment self-monitoring capabilities, *see* Pt 9, Ch 1,2.10.7, are to include at least:~~
- ~~facilities to monitor for system lock-ups (program hangs);~~
- ~~means to detect whether starting, shut-down and control command data communication links are operational; and~~
- ~~power supply failure including as a result of internal fuse or protective device operation.~~

15.5 Control engineering systems

15.5.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 9, Ch 1, as applicable.

15.5.2 The engine control, alarm, monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shut-downs, etc.) of this Chapter and Pt 9, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration identifying:
(a) Local and remote means to carry out system configuration.
(b) Engine packager or system integrator procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Engine builder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application.
Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request, in accordance with Pt 9, Ch 1,1.4 and 6.1.3.

15.6 Software

15.6.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 9, Ch 1,2.10.21, 2.13.2 and 2.13.7.

15.6.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the engine packager or system integrator. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

15.6.3 To demonstrate compliance with 15.6.1 and 15.6.2:
(a) software quality plans and safety evidence are to be submitted for consideration, *see* 15.2.2(b) and (c); and
(b) an assessment inspection of the engine packager’s or system integrator’s completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

~~15.5~~ 15.7 Emergency engines

~~*15.5.6*~~ *15.7.6* Where the proposed arrangement of engine electronic control systems does not incorporate redundancy to satisfy the requirements of ~~15.6.1~~ 15.3.1, evidence is to be submitted that demonstrates the arrangements have been assessed and found to comply with IEC 61508, functional safety of electrical/electronic/programmable electronic systems, or a relevant alternative standard. The submissions are to include proposals for LR to verify compliance (reviews, Surveys, trials, etc.) with the applicable standard(s).

Existing paragraphs 15.5.1 *to* 15.5.6 *have been renumbered* 15.7.1 *to* 15.7.6.

~~15.6 FMEA analysis~~

~~*15.6.1* Failure Mode and Effects Analysis (FMEA) is to demonstrate that a failure of the functioning of an electronic control system:~~

~~(a) Will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 9, Ch 1,2.5.7 and 2.12.2.~~

~~(b) Will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 9, Ch 1,2.13.4 and 2.12.5.~~

~~(c) Will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see* Pt 9, Ch 1,2.3.12, 2.4.5, 2.5.4, 2.10.4, 2.13.5.~~

~~*15.6.2* Where FMEA analyses are required to be carried out, the reports submitted need to address the following issues:~~

~~(a) Identify the standards used for analysis and system design.~~

~~(b) Identify the objectives of the analysis.~~

~~(c) Identify any assumptions made in the analysis.~~

~~(d) Identify the equipment, system or sub-system, mode of operation and the equipment.~~

~~(e) Identify potential failure modes and their causes.~~

~~(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode.~~

~~(g) Identify measures for reducing the risks associated with each failure mode. This may be through system design, provision of redundant systems and/or quality control procedures for sourcing, manufacture and testing.~~

~~(h) Identify trials and testing necessary to prove conclusions.~~

~~*15.6.3* At sub-system level it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.~~

~~*15.6.4* In an electronically controlled engine it is necessary to define the essential services on which the operation of the engine relies and the control functions, alarm functions and safety functions for the equipment and machinery providing these services, examples of essential services are:~~

~~(a) Starting arrangements.~~

~~(b) Fuel supply arrangements.~~

~~(c) Lubricating oil arrangements.~~

~~(d) Hydraulic oil arrangements.~~

~~(e) Cooling arrangements.~~

~~(f) Power supply arrangements.~~

~~*See also* Pt 1, Ch 2,17.~~

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Gas Turbines

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■ *Section 7*
Control, alarm and safety systems

7.9 Automatic and remote controls

7.9.2 ~~The following turbine services are~~ Where oil fuel grades require heating or cooling only, oil fuel supply is to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine~~:~~, *see also* 7.9.4.

~~(a) Lubricating oil supply.~~

~~(b) Exhaust gas.~~

7.9.4 Where the oil fuel supply is heated, automatic control for viscosity may be fitted in lieu of the temperature control required by 7.9.2.

Table 2.7.1 Gas turbine machinery: Alarms and shut-downs (*Part only shown*)

Item	Alarm	Note
Overspeed	High	Automatic shut-down, *see also* 7.2
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Starting hydraulic pressure	Low	—

Volume 2, Part 4, Chapter 1

Gas Turbines

Effective date 1 January 2012

■ *Section 7*

Propeller design

7.1 Minimum blade thickness

(*Part only shown*)

7.1.1 For propellers having a skew angle of ~~less than~~ 25° or less, as defined in 1.3.1, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase in each case due to fillets, and at 60 per cent radius, is to be not less than:

(*Part only shown*)

7.1.4 For propellers having skew angles of greater than 25° ~~or greater~~, but less than 50°, the mid-chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

Volume 2, Part 4, Chapter 2

Water Jet Systems

Effective date 1 January 2012

■ ~~*Section 1*~~

Scope

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 This Chapter gives requirements for fixed or steerable water jet propulsion systems where the rated power exceeds 500 kW, and which are integral with the ship's hull structure and form the main means of propulsion. The arrangements of water jet units for other purposes will be considered in relation to their intended duty.

1.1.3 A water jet propulsion unit is defined as a machine which takes in water, by means of a suitable inlet and ducting system, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system.

1.2 Redundancy

1.2.1 In general, a minimum of two water jet units are to be provided where these form the sole means of propulsion.

1.2.2 The failure of one water jet unit or its control system is not to render any other water jet unit inoperative.

1.2.3 Where a single water jet installation is proposed, it will be subject to special consideration, taking into account the proposed restricted area notation. A formal risk ~~assessment will be required in these cases.~~

■ ~~*Section 2*~~

Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Longitudinal section of the complete water jet unit.

2.2.2 Detailed dimension plans indicating scantlings and materials of construction of the following:

(a) Arrangement of the system, including intended method of attachment to the hull and building in, geometry of tunnel, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including impeller, and also stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This includes steerable exit water jet nozzles where fitted.
(d) Components of retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.
(f) Shaft sealing arrangements.
(g) Details of any shafting support or guide vanes used in ~~the water jet system.~~

~~*2.2.3* Schematic plans of the lubricating and hydraulic~~ systems, together with pipe material, relief valves and working pressures.

2.3 Calculations and information

2.3.1 Details of the power/speed range of operation indicating the maximum continuous torque rating together with flow rate and thrust.

2.3.2 Strength calculations, using the maximum continuous torque rating and the most ‘onerous’ operating condition, including short term high power operation, as a design case including the effects of mean and fluctuating loads, residual stresses, and stress raisers, for:

(a) Impeller and, if fitted, the stator and any bolting arrangements.

(b) Shaft supports and guide vanes if fitted.
In the absence of precise information, the fluctuating stress may be assumed to be 15 per cent of the maximum stress. As an alternative to fatigue strength calculation results of an approved measurement programme may be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum continuous rating condition.

(c) Detailed weld specification where an impeller has welded blades. Welds are to be full penetration type or of equivalent strength.

(d) Steering components, including lugs of steerable nozzles where fitted.

(e) Retractable buckets and associated mechanism, which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with appropriate full scale or model test data or satisfactory service experience to validate the design method.

2.3.3 Details of the Designer’s loadings and positions of application in the hull are to be submitted, and should include maximum applied thrust, moments and tunnel pressures. The tunnel strength and supporting structure are to be examined by direct calculation procedures and submitted for consideration.

2.3.4 Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.

2.3.5 Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

2.3.6 Torsional vibration calculations of the complete dynamic system in accordance with Pt 5, Ch 1 together with a torsional schematic of the water jet unit.

2.3.7 Shaft whirling calculations where required by Pt 5, Ch 3.

2.3.8 Details of control engineering aspects are to be in ~~accordance with Pt 9, Ch 1.~~

■ ~~*Section 3*~~
Materials

3.1 General

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials*.

3.1.2 Machinery components are to be of steel or other approved non-ferrous metals suitable for the intended environment.

■ *Section 4*
Design and construction

4.1 Shaftline

4.1.1 The diameter of the shafting is to comply with Pt 3, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

4.1.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected. Full details of the means of protection are to be submitted.

4.1.3 Where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force are to be forwarded for consideration. A factor of safety against slippage of 2,0, based upon mean plus vibratory torque, is to be achieved for couplings located inboard, and likewise 2,5 for couplings which are located outboard.

4.1.4 For the interference fit of keyless impellers the requirements of Chapter 1 are to be applied.

4.2 Shaft support system and guide vanes

4.2.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller, or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

4.2.2 Fatigue strength calculations of supports or guide vanes are to be submitted and are to include the effects of mean and fluctuating loads, residual stresses, and stress raisers. In general, the fillet radius should not be less than the maximum thickness at that location. Smaller radii may be considered for which the results of an approved measurement programme are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the designed operating conditions.

4.2.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or ~~boroscope inspection of these components.~~

~~4.3 Impeller~~

4.3.1 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

4.3.2 Where an impeller has bolted on blades, consideration is also to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

4.3.3 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes must be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

4.3.4 A calculation of the blade natural frequency for the impeller blades is to be undertaken. As such the natural frequency should be shown to lie outside any expected excitation frequencies within a speed range of 30 per cent below to 10 per cent above the maximum impeller speed. Deviations from these limits will be considered.

4.3.5 A facility for the in service inspection of the impeller and stator (if fitted) blades is to be provided which will allow for either a direct visual or boroscope inspection of the complete blade surfaces.

4.4 Stator

4.4.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydro-dynamic and mechanical loads (including any loads transmitted via shaft bearings) developed by the unit and reacted through the blades when the impeller is absorbing full power and the vessel is either free running or undergoing a crash stop manoeuvre, whichever imposes the greater loading on the blades.

4.4.2 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

4.4.3 If the stator ring is a composite assembly then consideration is also to be given to the distribution of stress in the various adjacent members.

4.4.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to be carried out and it is to be demonstrated that this does not coincide with the natural frequency of the stator blades over a speed range of 30 per cent below to 10 per cent above maximum impeller speed. Similarly this condition is to be demonstrated for the manoeuvring speeds.

4.4.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

4.4.6 Where the stator blading assembly forms part of the nozzle, the requirements of 4.6 must be considered in ~~association with those for the stator assembly.~~

~~4.5 Tunnel and securing arrangements~~

4.5.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure.

4.5.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

4.5.3 Consideration should be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard must strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

4.5.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separating of the flow into the rotating machinery.

4.5.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage, and to the axial location of rotating parts.

4.6 Nozzle and reversing bucket

4.6.1 Nozzles can be either of a fixed or steerable form. The design of the nozzle must fully take into account the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments and bucket loads which may be reacted through the body of the nozzle. In this analysis the changes to the pressure distribution caused by transient manoeuvres are to be considered.

4.6.2 Consideration is to be given to all transient loads the bucket is likely to experience from manoeuvring and the sea conditions.

4.6.3 The bucket is to be given reasonable mechanical protection from other impact damage such as collision with harbour walls, other vessels, buoys, etc.

4.7 Steering system

4.7.1 In general, the steering systems are to comply with the requirements of Pt 6, Ch 1.

4.7.2 In addition to the requirements of Pt 6, Ch 1, the steering mechanism is to be capable of turning the nozzle unit ~~at not less than 1,5 rev/min.~~

■ ~~Section 5~~

Piping systems

5.1 General

5.1.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 7, Ch 1.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Pt 7, Ch 3. Requirements for steering hydraulic systems are given in Pt 6, Ch 1.

5.2 Hydraulic power systems

5.2.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 7, Ch 1.

5.2.2 The hydraulic power operating systems for each water jet unit are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system; and

(b) a fixed storage tank having sufficient capacity to recharge at least one water jet power actuating system including the reservoir.

■ Section 6

Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 9, Ch 1.

6.1.2 Steering control is to be provided for the water jet from machinery control stations.

6.1.3 For water jets used as the only means of propulsion, a standby or alternative power source of actuating medium for controlling the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

6.1.4 Means are to be provided at each station to stop each water jet.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2 to 6.2.4 and Table 2.6.1.

6.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust.

6.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station ~~from which it is possible to control the reversal of thrust.~~

~~Table 2.6.1 Alarms~~

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Hydraulic system flow	Low	—
Lubricating oil pressure	Low	—
Control system	Fault	—
Control system power supply	Failure	—

6.2.4 The alarms described in Table 2.6.1 are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 9, Ch 1.

■ Section 7

Electrical systems

7.1 Distribution arrangements

7.1.1 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control ~~circuits.~~

■ Section 1

Scope

1.1 General

1.1.1 For the purposes of these Rules, a water jet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The water jet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the water jet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine water jet propulsion systems and is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.3 The requirements for a fixed or steerable water jet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the water jet unit.

1.1.4 These requirements relate to water jets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2*
General requirements

2.1 Water jet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two water jet systems is to be provided where these form the sole means of propulsion. For ships where a single water jet system is the sole means of propulsion or steering, a detailed engineering and safety justification is to be evaluated by LR, *see* 2.3.22. This evaluation process will include a risk assessment analysis, using a recognised technique, to verify that sufficient levels of redundancy and monitoring are incorporated in the water jet unit's essential support systems and operating equipment.

2.1.2 Water jet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see* Pt 1, Ch 2,4 and within the operational service profiles defined by 2.3.11 and 2.3.12.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in Pt 1, Ch 2,4. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in 2.3 and 2.4, are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:
(a) Shafting assembly indicating bearing positions;
(b) Steering assembly;
(c) Reversing assembly;
(d) Shaft sealing arrangement assembly;
(e) Longitudinal section of the complete water jet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:
(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc;
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted;
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit water jet nozzles, where fitted;
(d) Components of the retractable buckets where these are used for providing astern thrust;
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication;
(f) Details of any shafting support or guide vanes used in the water jet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see* 2.3.12, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:
(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads;
(b) Shaft supports and coupling arrangements;
(c) Inlet guide vanes, if fitted;
(d) Steering components, including the lugs of steerable nozzles, where fitted;
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft, including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with Pt 3, Ch 2.

2.3.4 Torsional vibration calculations of the complete dynamic system, in accordance with the relevant requirements included in Pt 5, Ch 1.

2.3.5 Shaft lateral vibration calculations, where required by Pt 5, Ch 3.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the water jet.

2.3.12 The water jet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the water jet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the water jet system will meet the self-priming criteria, *see* 3.1.6.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength are to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design, in accordance with Pt 9, Ch 1.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured, is to be defined together with a justification.

2.3.21 Details of the water jet's loading reactions, together with the positions of application within the hull; they are to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The water jet unit's rated flow and head.

2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see* 2.4.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. These are to include any in-water engineering procedures, where recommended by the water jet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single water jet system is the ship's sole means of propulsion, *see* 2.2.3. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in Table 2.17.1 in Pt 1, Ch 2,17 or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedures for Failure Mode and Effects Analysis*, or the IMO *Code of Safety for High Speed Craft, 2000, Annex 4 – Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed, to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.4.1.

2.4.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see* Pt 1, Ch 2,17.1.5.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3*
Design requirements

3.1 General

3.1.1 The arrangement of water jet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum service speed. Results of the trials are to be recorded.
(d) Astern running conditions for the ship.

3.1.2 The mean loadings are those loadings induced by the water jet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the water jet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades, using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components is to comply with Pt 3, Ch 2. For calculation purposes, the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with seawater, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in Pt 3, Ch 2,4.4.7.

3.2.4 The use of composite shafts is permitted, *see* 2.3.16.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, a factor of safety of 1,5 is to be achieved for the design of the bolted connection when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of Pt 3, Ch 2,4.12 are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of Pt 5, Ch 7,3.2 of the *Rules and Regulations for the Classification of Ships*, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft', respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out, which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of water jet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:
- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see* 3.1.1.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the boss and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the water jet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by 3.1.1 or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade-passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the water jet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of 3.7 are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage, as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure is to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of Pt 6, Ch 1.

3.7.2 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface, together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.3 In addition to the requirements of Pt 6, Ch 1, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO Resolution MSC.137(76), *Standards for Ship Manoeuvrability*.

3.7.4 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.5 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations, as specified in the FMEA, and where indicated by the manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

■ *Section 4*
Piping systems

4.1 General

4.1.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 7, Ch 1.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of Pt 7, Ch 3; in addition, steering hydraulic systems are to comply with the applicable requirements of Pt 6, Ch 1.

■ *Section 5*
Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with Pt 9, Ch 1.

5.1.2 For water jets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device that controls the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.3 Means are to be provided at each control station to stop each water jet.

5.2 Monitoring and alarms

5.2.1 In addition to the requirements of Pt 6, Ch 1, alarms and monitoring requirements are indicated in 5.2.2 to 5.2.4 and Table 4.5.1.

Table 4.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Lubricating oil temperature	High	—
Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversing system

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with water jet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 9, Ch 1.

■ *Section 6*
Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of Pt 10, Ch 1.

6.1.2 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7*
Inspection, testing and fitting of water jets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process, and is to meet the requirements of ISO 1940 Grade G6,3 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required, unless otherwise agreed by the manufacturer and LR.

7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.
(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system; *see* Ch 4,8 for austenitic stainless steels and Ch 8,3 for aluminium alloys of the Rules for Materials.
(c) The quality of the fit of the impeller boss on the shaft taper.
(d) The fitting of the impeller to the shaft and its subsequent functional testing.
(e) The finished surfaces of the impeller boss, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of water jet systems

7.2.1 The completed water jet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve, relative to temperature, and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the water jet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with Pt 7, Ch 1.

7.3 Sea trial requirement

7.3.1 The following requirements are to be complied with:

- Pt 1, Ch 2,16 for sea trials.
- Pt 1, Ch 2,15.4 for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the water jet are to be the subject of harbour and then sea trials. Demonstration of the requirements of Pt 9, Ch 1 is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the water jet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see* 2.4.4, are to be carried out.

■ *Section 8*
Installation, maintenance and replacement

8.1 General

8.1.1 All water jet system propulsion units are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See* 2.3.24.

8.1.2 The manual required by 8.1.1 is to be placed on board and is to contain the following information:

(a) Description of the water jet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of the system on board ship, with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.
(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment, where applicable.
(f) Actions required in the event of fault/failure conditions being detected.
(g) Precautions to be taken by personnel working during installation and maintenance.

Volume 2, Part 4, Chapter 4
Podded Propulsion Units

Effective date 1 January 2012

■ *Section 1*
Scope

1.1 Application

1.1.3 The requirements of this Chapter relate to podded propulsion units powered by electric propulsion motors (and are in addition to the requirements for Electric Propulsion in Pt 10, Ch 1,16 and other relevant Sections). Podded propulsion units with other drive arrangements will be subject to individual consideration.

■ *Section 2*
General requirements

2.5 Failure Modes and Effects Analysis (FMEA)

2.5.1 An FMEA is to be carried out where a single podded propulsion unit is the vessel's sole means of propulsion, *see* 2.1.1. The FMEA is to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure. The assessment required by Pt 10, Ch 1,16.2.2 may be considered for demonstrating the acceptability of the proposed design for propulsion power purposes.

■ *Section 7*
Electrical equipment

7.1 General

7.1.4 Details are to be submitted to demonstrate the suitability of cables and busbars intended to operate at temperatures exceeding 95°C, *see* Pt 10, Ch 1,7.2.2 and 11.4.3.

7.2 Slip rings

7.2.1 Where slip rings are incorporated in the design, the details of the following are to be submitted for consideration:

(a) temperature rise test reports;
(b) maximum permitted temperature ratings and design operating temperatures for materials;
(c) where applicable, arrangements for forced air or liquid cooling;
(d) for data communication link slip rings, evidence to demonstrate compliance with Pt 9, Ch 1,2.11.3;
(e) suitability for use under the conditions of vibration expected to arise in normal operation;
(f) evidence of satisfactory operation under the normal angles of inclination given in Pt 10, Ch 1,1.10;
(g) cable securing arrangements; and
(h) evidence of electromagnetic compatibility of control, alarm and safety systems with power circuits.

7.2.2 Where forced cooling is used on slip rings, an alarm is to be initiated to indicate the failure of the forced cooling and it is to be possible to operate the slip ring at a reduced power level defined by the manufacturer in the event of failure of the forced cooling.

■ *Section 8*
Control engineering ~~systems~~ arrangements

8.1 General

8.1.3 Steering control is to be provided for podded drives from the navigating bridge~~, the main machinery control station~~ and locally.

8.2 Monitoring and alarms

8.2.1 The requirements for alarms and monitoring arrangements are to be in accordance with Pt 6, Ch 1,8.1 and Table 4.8.1. These alarms are in addition to the requirements of Pt 10, Ch 1,16.

Table 4.8.1 **~~Specific alarms for pod control systems~~ Additional alarms and safeguards for podded propulsion units**

Item	Alarm	Note
Podded drive azimuth angle	—	Indicator, *see* 8.1.4
Propulsion motors	~~Overload, power failure~~ Power supply failure	To be indicated on the navigating bridge
Propulsion motor power limitation or automatic reduction	Activated	*See also* ~~8.2.8~~ Pt 10, Ch 1,16.4.9
Hydraulic oil system pressure	Low	To be indicated on the navigating bridge
Bearing temperature	High	For grease lubricated bearings
Motor temperature	High	*See* Pt 10, ~~Ch 1,5.1.4~~ Ch 1,16.1.4
Lubricating oil supply pressure	Low	If separate forced lubrication for shaft bearings; to be indicated on the navigating bridge
Lubricating oil temperature	High	*See also* Pt 10, Ch 1,16.5.9
Lubricating oil tank level for motor bearings	Low	—
Water in lubricating oil for motor bearings	High	Required for single podded propulsion units only
Motor cooling air inlet temperature	High	—
Motor cooling air outlet temperature	High	—
Motor cooling air flow	Low	—
Shaft bearing vibration monitoring	High	*See* 6.3.10. Monitoring is to allow bearing condition to be gauged using trend analysis
Shaft sealing	Water ingress	*See* 6.3.13
Dry space water pump operation	Abnormal	Alarm set to indicate a frequency or duration exceeding that which would normally be expected
Dry space water level	~~High~~ 1st stage high 2nd stage high	— Propulsion motor is to shut down automatically, *See* Note
Slip ring forced cooling	Failure	*See* 7.2.2

NOTE
The second stage dry space water level high alarm is not needed where the electrical equipment installed within the pod is suitable for operation in flooded spaces, *see* 6.8.1.

Volume 2, Part 6, Chapter 1

Steering Gear

Effective date 1 January 2012

■ *Section 8*

Monitoring and alarms

8.1 Monitoring

8.1.1 Alarms and monitoring requirements are indicated in ~~8.1.2, 8.1.3~~ 8.1.2 to 8.1.4 and Table 1.8.1.

8.1.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

Table 1.8.1 **Alarms** (*Part only shown*)

Item	Alarm	Note
Angular position of the Steering Mechanism	— Failure	Indication, *see* 8.1.2 *See* 8.1.4
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations, *see* 7.1.2 and 7.1.3
Control system	Failure	*See* 8.1.4

Volume 2, Part 7, Chapter 1

Piping Design Requirements

Effective date 1 January 2012

■ *Section 5*
Pipe connections

5.10 Mechanical connections for piping

Table 1.5.3 Application of mechanical joints *(Part only shown)*

Systems	Kind of connections		
	Pipe unions	Compression Couplings (6)	Slip-on Joints
Sea-water			
Bilge lines	+	+	+1
~~Fire main~~ HP sea-water and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Chilled water systems	+	+	+1
Condensate return	+	+	+1
Made water and demineralised water system	+	+	+
Non-essential system	+	+	+
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Intakes and uptakes (8)			
HVAC trunking (8)			
Miscellaneous			
~~Starting/Control air (1)~~	~~+~~	~~+~~	~~—~~
~~Service air (non-essential)~~	~~+~~	~~+~~	~~+~~
High pressure (HP) air systems (1)	+	+	—
Medium pressure (MP) air systems (Starting air) (1)	+	+	—
Low pressure (LP) air systems (incl. Control air) (1)	+	+	—
Brine	+	+	+
CO_2 system	+	+	—
Nitrogen system	+	+	—
Steam	+	+	+7

NOTES

8. Requirements for HVAC trunking or gas turbine updates and intakes are addressed in the relevant Sections of the Rules.

■ *Section 11*
~~Plastic piping and components~~
Pipe connections

11.4 Fire performance criteria

11.4.1 Where plastics pipes are used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings, including couplings with flexible internal seals, are to be of a type which has been fire endurance tested in accordance with the requirements of Table 1.11.3.

Volume 2, Part 7, Chapter 2

Ship Piping Systems

Effective date 1 January 2011

■ *Section 1*
General requirements

1.2 Plans and particulars

1.2.1 At least three copies of the following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:

- Arrangements of air pipes and closing appliances to tanks and enclosed spaces.
- Sounding arrangements for all tanks and enclosed spaces.
- Arrangements of level alarms fitted in tanks, machinery spaces and any other spaces.
- Arrangements of any cross-flooding or heeling tank systems.
- Bilge drainage and dewatering arrangements to all compartments which are to include details of location, number and capacity of pumping units on bilge and dewatering service.
- Ballast filling and drainage arrangements.
- Tank overflow arrangements.
- Details verifying compliance with the sizing of air pipes required by 10.8.
- Details verifying compliance with 10.3.3 for tanks that can be replenished at sea with design ship movements and filling rates stated.
- Operating manuals and maintenance instructions are to be provided on board and submitted for information where requested by LR. The manuals are to include particulars, description, operating instructions and maintenance instructions for all systems.

■ *Section 10*
Air, overflow and sounding pipes

10.6 Air pipe closing appliances

10.6.4 Air pipe automatic closing devices are to be so designed that they will withstand both ambient conditions, as indicated in Pt 1, Ch 2,4.4 and 4.5, and designed working conditions, and be suitable for use at inclinations up to and including ±40°.

10.6.5 Air pipe automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

10.6.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

10.6.7 Air pipe automatic closing devices are to be self-draining.

10.6.8 The clear area through an air pipe closing device in the open position is to be at least equal to the area of the inlet.

10.6.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

10.6.10 The maximum allowable tolerances for wall thickness of floats are not to exceed ±10 per cent of thickness.

10.6.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

10.6.12 Casings of air pipe closing devices are to be of approved metallic materials, adequately protected against corrosion.

10.6.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

10.6.14 For areas of the head susceptible to erosion (e.g., those parts directly subjected to ballast water impact when the tank is being pressed up, such as the inner chamber area above the air pipe plus an overlap of 10° or more either side), an additional harder coating should be applied. This is to be an aluminium-bearing epoxy, or other equivalent coating, applied over the zinc.

10.6.15 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and in sea-water, and suitable for operating at ambient temperatures between –25°C and 85°C.

10.6.16 The requirements do not apply to arrangements for refuelling underway.

Volume 2, Part 7, Chapter 3

Machinery Piping Systems

Effective date 1 January 2012

■ *Section 1*
General requirements

1.2 Plans and particulars

(*Part only shown*)

1.2.1 Three copies of the following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of novel or special character affecting classification.

- Arrangements of flammable liquids used for ~~power transmission,~~ control and heating systems.
- Arrangements of services for power transmission systems which are essential for safety or for the operation of the ship at sea.

- Arrangements and dimensions of all steam and thermal fluid pipes where the design pressure or temperature exceeds 16,0 bar (16,3 kgf/cm^2) or 300°C, respectively, and the outside diameter exceeds 76,1 mm, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
- Operating manuals and maintenance instructions are to be provided on board and submitted for information where requested by LR. The manuals are to include particulars, description, operating instructions and maintenance instructions for all systems.

■ *Section 2*
Oil fuel – General requirements

2.1 Flash point

~~*2.1.5* Tanks containing oil fuel are to be separated from vehicle spaces, crew, embarked personnel, passenger and baggage compartments by either:~~

- ~~a cofferdam formed by a gastight steel division additional to the division which retains the oil, and which is suitably ventilated and drained, or~~
- ~~a division of all welded steel construction, designed and tested to withstand a head of water at least 1,5 metres greater than the maximum service head.~~

2.11 Tanks and cofferdams

2.11.1 Tanks containing oil fuel are to be separated from vehicle spaces, crew, embarked personnel, passenger and baggage compartments by a gastight and watertight boundary or a cofferdam which is suitably ventilated and drained.

■ *Section 3*
Oil fuel burning arrangements

3.1 Oil burning units

3.1.1 All oil burning equipment is to be capable of operating at defined power/rating levels where specified by the Naval Authority. Confirmation by the manufacturer of this capability is to be provided to LR, including the specified power/rating parameters, and operating and maintenance regimes. *See also* Pt 1, Ch 2,4.1.2.

Existing paragraphs 3.1.1 *to* 3.1.4 *have been renumbered* 3.1.2 *to* 3.1.5.

3.1.6 In all dual oil fuel burning systems for boilers, the manufacturer of the combustion equipment is to ensure that the full system, including control and monitoring systems, is capable of continuous operation in all conditions for each fuel grade.

Existing paragraphs 3.1.5 *to* 3.1.11 *have been renumbered* 3.1.7 *to* 3.1.12.

■ *Section 4*
Oil fuel pumps, pipes, fittings, tanks, etc.

4.3 Relief valves on pumps

4.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in ~~close~~ closed circuit, i.e. arranged to discharge back to the suction side of the pump and effectively to limit the pump discharge pressure to the design pressure of the system.

■ *Section 8*
Lubricating oil systems

8.5 Maintenance of bearing lubrication

8.5.2 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see* Pt 10, Ch 1,1.9 and Section 9.

Volume 2, Part 7, Chapter 4

Aircraft/Helicopter/Vehicle Fuel Piping and Arrangements

Effective date 1 January 2012

■ *Section 2*
Refuelling facilities

2.1 Fuel storage

2.1.5 Storage tanks are to be of an approved construction and attention is to be given to inspection procedures, mounting and securing arrangements and electrical bonding of tanks and fuel transfer system. The internal surfaces of steel tanks are to be suitably coated with impervious paint to prevent corrosion. The coating is to comply with 2.5.1. Independent oil fuel tanks are to comply with the requirements of 2.2. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and should comply with the relevant Codes for the transportation of dangerous goods in ships.

2.2 Independent oil fuel tanks

2.2.1 Where separate oil fuel tanks are permitted, their construction is to be in accordance with the requirements of 2.2.2 to 2.2.6, *see also* SOLAS 1974 as amended Reg.II-2/B4.2.2.3.2.

2.2.2 In general, the minimum thickness of the plating of independent oil fuel tanks, where they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, less than 500 litres, the minimum thickness may be 3 mm.

2.2.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in Table 4.3.1. The stiffeners are to be of approved dimensions.

2.2.4 The dimension given in Table 4.2.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary of the tank.

Table 4.2.1 Plate thickness of independent oil fuel tanks

Thickness of plate, in mm	Head of bottom of tank to top of overflow pipe, in metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, in mm				
5	585	525			
6	725	645	590		
7	860	770	700	650	
8	1000	900	820	750	700
10	1280	1140	1040	960	900

2.2.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

2.2.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

2.2.7 Where independent tanks are for the storage of fuel with a flash point below 60°C, provisions are to be made for the measurement of oil fuel temperature at the pump suction pipe.

~~2.2~~ 2.3 Fuel pumping and filling

Existing paragraphs 2.2.1 *to* 2.2.16 *have been renumbered* 2.3.1 *to* 2.3.16.

~~2.3~~ 2.4 Refuelling aircraft/helicopters

Existing paragraphs 2.3.1 *to* 2.3.5 *have been renumbered* 2.4.1 *to* 2.4.5.

~~2.4~~ 2.5 Defuelling

Existing paragraphs 2.4.1 *to* 2.4.2 *have been renumbered* 2.5.1 *to* 2.5.2.

~~2.5~~ 2.6 Fuel contamination

Existing paragraphs 2.5.1 *to* 2.5.2 *have been renumbered* 2.6.1 *to* 2.6.2.

Volume 2, Part 7, Chapter 5

Ship Type Piping Systems

Effective date 1 January 2011

■ *Section 11*

Hydraulic power actuating systems

11.1 General

11.1.2 The arrangements for storage, distribution and utilisation of hydraulic and ~~other~~ flammable oils employed under pressure in power transmission systems, control and actuating systems ~~and heating systems in locations where means of ignition are present~~, heating systems and hydraulic media in systems which are providing essential services, are to comply with the provisions of Ch 3, 2.9.3, 2.9.4, 2.9.5, 4.2, 4.3, 4.5, 4.11 and 4.16 where applicable.

Volume 2, Part 8, Chapter 1

Steam Raising Plant and Associated Pressure Vessels

Effective date 1 January 2012

■ *Section 18*

Control and monitoring

18.2 Automatic and remote controls

18.2.3 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:

(a) Combustion system.
(b) Oil fuel supply temperature or viscosity, ~~heavy oil only~~ oil fuel grades requiring heating or cooling, as applicable.
(c) Boiler drum water level.
(d) De-aerator water level where applicable.
(e) Superheated steam pressure where applicable.
(f) Superheated steam temperature where applicable.
(g) De-superheated steam pressure where applicable.
(h) De-superheated steam temperature where applicable.

Volume 2, Part 9, Chapter 1

Control Engineering Systems

Effective date 1 January 2011

■ *Section 1*
General engineering systems

1.2 Plans and information

1.2.5 **Programmable electronic systems.** (In addition to the documentation required by 1.2.2.)

♣(a) System requirements specification.

♣(b) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.

♣(c) Details of power supply and data storage arrangements, *see* 2.10.9 and ~~2.12.6~~ 2.13.6.

♣(d) Hardware certification details, *see* 2.10.5 and ~~2.12.3~~ 2.13.3.

♣(e) Software quality plans, including applicable procedures, *see* ~~2.10.21~~ 2.10.25.

♣(f) Factory acceptance, integration, harbour and sea trial test schedules for hardware and software.

♣(g) System integration plan, *see* ~~2.13.2~~ 2.14.2.

♣(h) Failure Mode and Effects Analysis (FMEA), *see* ~~2.13.5~~ 2.14.5.

1.2.6 For wireless data communication equipment:

(a) details of manufacturer's installation and maintenance recommendations;

(b) network plan with arrangement and type of aerials and identification of location;

(c) specification of wireless communication system protocols and management functions, *see* 2.12.4;

(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

Existing paragraphs 1.2.6 *to* 1.2.10 *have been renumbered* 1.2.7 *to* 1.2.11.

■ *Section 2*
Essential features for control, alarm and safety systems

2.5 Control systems, general requirements

2.5.5 Remote or automatic controls are to be provided with sufficient instrumentation (e.g. alarms and indications) at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

2.5.7 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.13.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

2.10 Programmable electronic systems – General requirements

2.10.16 User interfaces are to ~~be designed in accordance with appropriate ergonomic principles to meet user needs and~~ enable timely access to desired information or control of functions. A system overview is to be readily available.

2.10.20 Display units are to comply with the requirements of ~~International Electrotechnical Commission Standard~~ an acceptable National or International Standard, e.g. IEC 60950:~~1991~~ 2005, ~~*Safety of information*~~ *Information technology equipment – Safety*, including electrical business equipment, in respect of emission of ionising radiation.

2.10.21 ~~Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.~~ The symbols used in mimic diagrams for the services listed in Pt 10, Ch 1,1.5.1 are to be consistent across all displays.

2.11 Data communication links

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* ~~2.12.2~~ 2.13.2.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also* 2.5.4.

Existing paragraphs 2.11.7 *to* 2.11.10 *have been renumbered* 2.11.8 *to* 2.11.11.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to 2.11 and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the ship, except as permitted by 2.12.3.

2.12.3 For services which need not be in operation continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis, and correction ensuring the received message is not corrupted or altered when compared to the transmitted message.
(b) Configuration and device authentication: is only to permit connection of devices that are included in the system design.
(c) Message encryption: protection of the confidentiality and/or criticality of the data content.
(d) Security management: protection of network assets, prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the ship is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner/Naval Authority and Operator.

~~2.12~~ 2.13 Programmable electronic systems – Additional requirements for Mobility category and safety critical systems

Existing paragraphs 2.12.1 *to* 2.12.10 *have been renumbered* 2.13.1 *to* 2.13.10.

~~2.13~~ 2.14 Programmable electronic systems – Additional requirements for integrated systems

Existing paragraphs 2.13.1 *to* 2.13.7 *have been renumbered* 2.14.1 *to* 2.14.7.

■ *Section 6*
Trials

6.1 General

6.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

6.4 Integrated platform management system failure

6.4.1 Where mobility type ship systems are operated through an Integrated Platform Management System (IMPS), a failure in the IMPS is not to render the ship's system inoperable and reversionary modes of operation are to be provided to ensure safe and graceful degradation and under these conditions any level of degraded performance should be defined and accepted by the Naval Authority.

~~6.4~~ 6.5 Record of trials

Existing paragraph 6.4.1 *has been renumbered* 6.5.1.

Volume 2, Part 10, Chapter 1
Electrical Engineering

Effective date 1 January 2012

■ *Section 1*
General requirements

1.2 Plans

1.2.5 Where required by 8.1.1, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:

(a) system design;
(b) operating philosophies, e.g. manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also* 1.2.16;
(d) general arrangement plans for the space in which the electrical equipment to be assessed is located, showing:
  - access to adjacent spaces;
  - the location of the electrical equipment;
  - ventilation arrangements for air conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs;
  - positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g. switching, equipment maintenance, instrument observation or cleaning, or where personnel could reasonably be expected to enter;

(e) calculations in accordance with 8.3;
(f) system operating procedures; and
(g) details of defined additional safety measures to be taken during activities.

Existing paragraphs 1.2.5 *and* 1.2.6 *have been renumbered* 1.2.6 *and* 1.2.7.

~~*1.2.7*~~ *1.2.8* Simplified circuit diagram of electrical propulsion system (where fitted) giving details of:

(a) ratings of electrical machines, transformers, batteries, dynamic braking assemblies and semiconductor converters;
(b) lubrication and cooling arrangements, where provided;
~~(b)~~(c) insulation type, size and current loadings of cables;
~~(c)~~(d) make, type and rating of circuit breakers and fuses;
~~(d)~~(e) instrumentation and protective devices;
~~(e)~~(f) earth fault indication/protection;
~~(f)~~ (g) ~~explanation of the system with details of the~~ propulsion control systems, and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of ~~Section 15.~~ 16.4; and
(h) harmonic analysis.

Existing paragraphs 1.2.8 *to* 1.2.21 *have been renumbered* 1.2.9 *to* 1.2.22.

1.5 Definitions

(*Part only shown*)

1.5.1 Essential services are those necessary for the propulsion and safety of the ship within the Mobility category and Ship Type category (*see* Pt 1, Ch 1,3) and include the following:

- scavenge blowers;
- steam raising plant, where steam is required for other essential services;
- steering gear;

1.5.15 An 'electric arc' is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.5.16 'Incident energy' is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.11 Location and construction

1.11.8 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

Existing paragraphs 1.11.8 *to* 1.11.10 *have been renumbered* 1.11.9 *to* 1.11.11.

1.11.12 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

Existing paragraphs 1.11.11 *and* 1.11.12 *have been renumbered* 1.11.13 *and* 1.11.14.

1.15 Labels, signs and notices

1.15.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

1.15.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with Table 1.1.1 will be considered to satisfy this requirement.

Table 1.1.1 Character height and viewing distance

Viewing distance (mm)	Minimum character height (mm)
Less than 500	2,3
500–1000	4,7
1000–2000	9,4
2000–4000	19

1.15.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

1.15.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:
- a word signalling the gravity of the risk (e.g. Danger, Warning or Caution)
- a statement of the nature and/or consequence of the hazard, and wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

~~1.15~~ 1.16 Operation under flooding conditions

Existing paragraphs 1.15.1 *and* 1.15.2 *have been renumbered* 1.16.1 *and* 1.16.2.

~~1.16~~ 1.17 Operation under fire conditions

Existing paragraphs 1.16.1 to 1.16.4 *have been renumbered* 1.17.1 *to* 1.17.4.

~~1.17~~ 1.18 Protection of electrical equipment against the effects of lightning strikes

Existing paragraph 1.17.1 *has been renumbered* 1.18.1.

~~1.18~~ 1.19 Electrical supplies to systems fulfilling military requirement

Existing paragraphs 1.18.1 *to* 1.18.4 *have been renumbered* 1.19.1 *to* 1.19.4.

~~1.19~~ 1.20 Programmable electronic systems

Existing paragraphs 1.19.1 *and* 1.19.2 *have been renumbered* 1.20.1 *and* 1.20.2.

■ *Section 6*
System design – Protection

6.13 Harmonic filters

6.13.1 Harmonic filters' final sub-circuits are to be protected individually against overload and short-circuit.

6.13.2 An alarm is to be initiated in the event of protective device operation.

6.13.3 Where parallel harmonic filters are used, an alarm is to be initiated in the event of current imbalance that could lead to failure of a harmonic filter.

■ *Section 7*
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC ~~60439~~ 61439: Low voltage switchgear and control gear assemblies;

(b) IEC 62271-200: *AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;

(c) ~~IEC 60466: AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV;~~ IEC 62271-201: High-voltage switchgear and control gear – Part 201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV;

(d) IEC 60255: *Electrical Relays*;

(e) an acceptable and relevant National Standard; or

(f) specialised acceptable and relevant Naval Standards.

In addition, the requirements of 7.2 to 7.19 are to be complied with.

7.12 Instrument scales

7.12.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second, or as agreed by the Naval Authority.

■ *Section 8*
Protection from electric arc hazards within electrical equipment

8.1 General

8.1.1 An assessment is to be carried out in accordance with 8.2.1 for all electrical equipment within which an arcing fault could occur, such as:
- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards;
- transformers.

8.2 Hazard identification and assessment

8.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in 8.1.1. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety.

Details of the following are to be submitted:
(a) each task to be performed, e.g. switching, equipment maintenance, instrument observation or cleaning;
(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;
(c) the methods to be used to help to prevent electric arcs;
(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

8.3 Calculations to be submitted

8.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:
(a) Calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;
(b) The maximum incident energy at the intended working distance in the case of an arcing fault;
(c) The distance from each conductor at which the incident energy would be 5 Joules per centimetre squared in the case of an arcing fault when the enclosure door is open.

These calculations may be made in accordance with IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, or another relevant Standard acceptable to LR.

8.4 Testing and trials

8.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

■ *Section ~~8~~ 9*
Rotating machines

~~8.1~~ 9.1 General requirements

9.1.11 A high bearing temperature alarm is to be provided where the following rotating machines are supplied with forced lubrication:
- generators of 100 kW and above; and
- electric propulsion motors.

9.1.12 A low lubricating oil pressure alarm is to be provided for generators and electric propulsion motors that are supplied with forced lubrication.

9.1.13 A high lubricating oil temperature alarm is to be provided for electric propulsion motors that are supplied with forced lubrication.

Existing sub-Sections 8.2 *to* 8.5 *have been renumbered* 9.2 *to* 9.5.

~~8.6~~ 9.6 Machine enclosure

~~8.6.1~~ 9.6.1 Where ~~water~~ liquid-cooled heat exchangers are used in the machine cooling circuit there is to be provision ~~for the detection of water~~ to detect leakage of the liquid, and the system is to be arranged so as to prevent the entry of ~~water~~ liquid into the machine.

Existing sub-Section 8.7 *has been renumbered* 9.7.

~~8.8~~ 9.8 Survey and testing

Existing paragraph 8.8.1 *has been renumbered* 9.8.1.

~~8.8.2~~ 9.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered, *see also* Section 16. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

Existing paragraphs 8.8.3 *and* 8.8.4 *have been renumbered* 9.8.3 *and* 9.8.4.

■ *Section ~~9~~ 10*
Converter equipment

~~9.1~~ 10.1 Transformers

Existing paragraphs 9.1.1 *to* 9.1.10 *have been renumbered* 10.1.1 *to* 10.1.10.

10.1.11 Transformers for propulsion power are to be provided with arrangements such that, in the event of excessive winding temperature, an alarm is initiated and:
- the load is reduced to a level commensurate with the cooling arrangements; or
- automatic shut-down of the transformer occurs.

~~9.1.11~~ 10.1.12 Where ~~water~~ liquid-cooled heat exchangers are used in transformer cooling circuits, there is to be provision ~~for the detection of water~~ to detect leakage of the liquid, and the system is to be arranged so as to prevent the entry of ~~water~~ liquid into the transformer.

Existing paragraph 9.1.12 *has been renumbered* 10.1.13.

■ Section ~~10~~ 11
Electric cables and busbar trunking systems (busways)

Existing sub-Section 10.1 *has been renumbered* 11.1.

~~10.2~~ 11.2 Testing

(*Part only shown*)

~~10.2.1~~ 11.2.1 Routine tests, consisting of at least:

(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of ~~the relevant publication or National Standard referred to in 10.1.2~~ IEC 60885-2, *Electrical test methods for electric cables. Part 2: Partial discharge tests*, or an acceptable National Standard, at the manufacturer's works prior to despatch.

Existing sub-Section 10.3 *has been renumbered* 11.3.

~~10.4~~ 11.4 Operating temperature

Existing paragraph 10.4.1 *has been renumbered* 11.4.1.

~~10.4.2~~ 11.4.2 The maximum rated conductor temperatures for normal and short circuit operation, for the insulating materials included within the standards referred to in ~~10.1.2~~ 11.1.2 are not to exceed the values stated in ~~Table 1.10.2~~ Table 1.11.2.

Existing paragraph 10.4.3 *has been renumbered* 11.4.3.

Existing Table 1.10.1 *has been renumbered* Table 1.11.1,

~~Table 1.10.2 Maximum rated conductor~~ temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short circuit
Thermoplastics:		
– Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	60	150
– Based upon polyethylene	60	130
Elastomeric or thermosettings:		
– Based upon ethylene propylene rubber or similar (EPM or EPDM)	85	250
– Based upon chemically crosslinked polyethylene	85	250
– Based upon silicon rubber	95	To be submitted
Mineral	95	To be submitted

Table 1.11.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short-circuit
Thermoplastic based upon: Vinyl acetate	70	150
Elastomeric or thermosetting, based upon:		
Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
High modulus or hard grade ethylene propylene rubber	90	250
Cross-linked polyethylene	90	250
Ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	90	250
High modulus or hard grade halogen-free ethylene propylene rubber	90	250
Halogen-free cross-linked polyethylene	90	250
Cross-linked polyolefin material for halogen-free cables	90	250
Halogen-free silicone rubber	95	350

~~10.5~~ 11.5 Construction

Existing paragraphs 10.5.1 *and* 10.5.2 *have been renumbered* 11.5.1 *and* 11.5.2.

~~10.5.3~~ 11.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and comply with the performance requirements of the appropriate part of IEC 60331: *Tests for electric cables under fire conditions – Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:

IEC 60331-1: *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*;
IEC 60331-21: *Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*;
IEC 60331-23: *Procedures and requirements – Electric data cables*;
IEC 60331-25: *Procedures and requirements – Optical fibre cables*. ~~; or~~
~~IEC 60331-31: *Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*, where the overall diameter of the cable exceeds 20 mm.~~

Existing paragraphs 10.5.4 *to* 10.5.9 *have been renumbered* 11.5.4 *to* 11.5.9.

~~10.6~~ 11.6 Conductor size

Existing paragraphs 10.6.1 *and* 10.6.2 *have been renumbered* 11.6.1 *and* 11.6.2.

(*Part only shown*)

~~10.6.3~~ 11.6.3 The cable current ratings given in Tables ~~1.10.3~~ 1.11.3 and ~~1.10.4~~ 1.11.4 are based on the maximum rated conductor temperatures given in Table ~~1.10.2~~ 1.11.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table ~~1.10.4~~ 1.11.4, may be applied using the data provided in:

Existing sub-Sections 10.7 *to* 10.18 *have been renumbered* 11.7 *to* 11.18.

~~Table 1.10.3 Electric cable current ratings, normal operation, based on ambient 45°C~~

Nominal cross section	Continuous r.m.s current rating, in amperes								
	Thermoplastic, PVC, PE			EP rubber and crosslinked PE			Silicon rubber or mineral		
	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core
0,75	6	5	4	13	11	9	17	14	12
1	8	7	6	16	14	11	20	17	14
1,25	10	8	7	18	15	13	23	19	16
1,5	12	10	8	20	17	14	24	20	17
2	13	11	9	25	21	17	31	26	21
2,5	17	14	12	28	24	20	32	27	22
3,5	21	18	14	35	30	24	39	33	27
4	22	19	15	38	32	27	42	36	29
5,5	27	23	19	46	39	32	52	44	36
6	29	26	20	48	41	34	55	47	39
8	35	30	24	59	50	41	66	56	46
10	40	34	28	67	57	47	75	64	53
14	49	42	34	83	71	58	94	80	66
16	54	46	38	90	77	63	100	85	70
22	66	56	46	110	93	77	124	105	87
25	71	60	50	120	102	84	135	115	95
30	80	68	56	135	115	94	151	128	106
35	87	74	61	145	123	102	165	140	116
38	92	78	64	155	132	108	175	149	122
50	105	89	74	185	153	126	200	175	140
60	123	104	86	205	174	143	233	198	163
70	135	115	95	225	191	158	255	217	179
80	147	125	103	245	208	171	278	236	195
95	165	140	116	275	234	193	310	264	217
100	169	144	118	285	242	199	320	272	224
120	190	162	133	320	272	224	360	306	252
125	194	165	134	325	280	230	368	313	258
150	220	187	154	365	310	256	410	349	287
185	250	213	175	415	353	291	470	400	329
200	260	221	182	440	375	305	494	420	346
240	290	247	203	490	417	343	570	485	400
300	335	285	235	560	476	392	660	560	460

Table 1.11.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm²)	Continuous r.m.s. current rating, in amperes								
	Thermoplastic (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicone rubber (95°C)		
	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	40	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	51	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

~~**Table 1.10.4 Electric cable current ratings, r.m.s. short circuit current**~~

Nominal cross section	Fault current at 250°C duration			Fault current at 150°C duration			Fault current at 130°C duration		
	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA
1	0,1	0,2	0,5	0,1	0,2	0,4	0,1	0,2	0,3
1,5	0,2	0,3	0,7	0,2	0,3	0,5	0,2	0,3	0,5
2,5	0,4	0,5	1,1	0,3	0,4	0,9	0,3	0,4	0,8
4	0,6	0,8	1,8	0,5	0,7	1,5	0,4	0,6	1,3
6	0,9	1,2	2,8	0,7	1,0	2,2	0,6	0,9	2,0
10	1,5	2,1	4,6	1,2	1,6	3,7	1,0	1,5	3,3
16	2,3	3,3	7,4	1,9	2,6	5,9	1,7	2,4	5,3
25	3,6	5,2	12	2,9	4,1	9,2	2,6	3,7	8,2
35	5,1	7,2	16	4,1	5,8	13	3,6	5,2	12
50	7,3	10	23	5,8	8,2	18	5,2	7,4	16
70	10	14	32	8,2	12	26	7,3	10	23
95	14	20	44	11	16	35	9,9	14	31
120	17	25	55	14	20	44	13	18	40
150	22	31	69	17	25	55	16	22	49
185	27	38	85	22	31	68	19	27	61
240	35	49	110	28	40	89	25	35	79
300	44	62	140	35	50	110	31	44	100

Table 1.11.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1s duration	0,5s duration	0,1s duration	1s duration	0,5s duration	0,1s duration	1s duration	0,5s duration	0,1s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69.0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82.8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

~~**Table 1.10.5 Correction factors**~~

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
PVC, Polyethylene	1,29	1,15	1,00	0,82	—	—	—	—	—	—	—
EPR, XLPE	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	—	—
Mineral, Silicon rubber	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 1.11.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	–	–	–	–	–
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	–
Elastomeric or thermosetting, based on silicone rubber (95°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Existing Table 1.10.6 *has been renumbered* Table 1.11.6.

Existing Table 1.10.7 *has been renumbered* Table 1.11.7.

Existing Table 1.10.8 *has been renumbered* Table 1.11.8.

Existing Table 1.10.9 *has been renumbered* Table 1.11.9.

Existing Sections 11 *to* 14 *have been renumbered* 12 *to* 15.

■ *Section ~~15~~ 16*

Electric propulsion

~~15.1~~ 16.1 General

Existing paragraphs 15.1.1 *to* 15.1.3 *have been renumbered* 16.1.1 *to* 16.1.3.

16.1.4 Propulsion motors, generators and converters are to be provided with means to prevent the accumulation of moisture and condensate when operating at low power levels, or when idle.

16.2 System design and arrangement

16.2.1 In general, for a ship to be assigned an unrestricted service notation, it is to have two independently driven propellers or other propulsion devices, each connected with at least one electric motor, where these form the sole means of propulsion.

16.2.2 For vessels where a propulsion device driven by electric motors is proposed as the sole means of propulsion, at least two effective, independent electric propulsion motors are to be provided and the system is to be designed in accordance with Pt 1, Ch 5. The risk management process is to identify components where a failure could cause loss of propulsion power or other essential services and the proposed arrangements for preventing and mitigating the effects of such a failure.

~~15.2~~ 16.3 Power requirements

Existing paragraphs 15.2.1 *to* 15.2.6 *have been renumbered* 16.3.1 *to* 16.3.6.

16.3.7 Where a central power generation system is employed, means are to be provided to connect available generator sets to meet the power requirement of the electric propulsion system. Arrangements are to be in place to prevent generator sets being automatically disconnected during ship manoeuvres.

16.3.8 Where forced cooling is used on propulsion motors, it is to be possible to operate the motor at a defined reduced power level in the event of failure of the forced cooling.

16.3.9 Total harmonic distortion of the a.c. voltage waveform up to 10 per cent on electric propulsion circuits, not directly connected to the main source of electrical power, may be considered where details are submitted which demonstrate that the equipment and systems are capable of operating under such conditions.

~~15.3~~ 16.4 Propulsion control

Existing paragraphs 15.3.1 *to* 15.3.5 *have been renumbered* 16.4.1 *to* 16.4.5.

~~15.3.6~~ 16.4.6 Control ~~stations~~, alarm and safety systems for the propulsion system are to satisfy the requirements of Pt 9, Ch 1.

Existing paragraphs 15.3.7 *and* 15.3.8 *have been renumbered* 16.4.7 *and* 16.4.8.

16.4.9 Means are to be provided to identify the cause of propulsion motor power limitation or automatic reduction (e.g. excessive load torque, cooling failure, high temperature, power availability).

Existing paragraph 15.3.9 *has been renumbered* 16.4.10.

~~*15.3.10* The propulsion control may be in analogue or digital form, which is to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements listed above. A quality plan giving evidence of compliance with this requirement is to be submitted when requested.~~

16.4.11 Control systems are not to share hardware or data communication links with control, safety and alarm systems not associated with propulsion control, *see also* Pt 9, Ch 1,2.11.

~~15.4~~ 16.5 Protection of propulsion system

~~15.4.1~~ 16.5.1 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to plant.

16.5.2 Propulsion motors are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals.

16.5.3 Propulsion converters are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals or connection to a propulsion motor with a stalled or locked rotor.

16.5.4 Electric motors of podded propulsion units, and/or propulsion motors having permanent magnet excitation, are to be provided with a protective device which, in the event of a short-circuit in the motor or in the cables between the motor and its circuit breaker, will instantaneously open the circuit-breaker and, in motors with electromagnetic excitation, de-excite the motor. Motors with permanent magnet main excitation are to be provided with means to prevent further damage as a result of continued rotation after disconnection (e.g., shaft brake).

~~15.4.2~~ 16.5.5 Safeguards for protecting propulsion equipment against damage resulting from earth faults are to be as specified by the equipment manufacturer. ~~The main propulsion circuits are to be provided with means for detecting earth faults.~~ Where the fault current flowing is liable to cause damage to the electrical equipment, there are to be arrangements for interrupting the current automatically.

~~15.4.3~~ 16.5.6 For the protection of electrical equipment and cables against overvoltages, means are to be provided for limiting the induced voltage when field windings and other inductive circuits are opened. Protective resistors and devices are to be sized to cater for the likely extreme operating conditions.

16.5.7 An alarm is to be initiated when the excitation system of electric generators providing propulsion power is overloaded such that damage due to heating could occur in the generator or its cabling.

~~15.4.4~~ 16.5.8 Where, on stopping or reversing the propeller, regenerated energy is produced by the propulsion motor, this is not to cause a dangerous increase of speed in the prime mover or a dangerous overvoltage condition on the supply system. Where a central power generation system is used, then the voltage and frequency fluctuations are not to exceed the limits given in 1.7.

16.5.9 Dynamic braking resistors are to be suitably rated for their expected operation.

16.5.10 Loss of flow of air or liquid cooling of propulsion converters, where used, is to initiate an alarm at an attended control position. Loss of flow of air or liquid cooling is not to result in immediate damage to the propulsion converter, *see* 9.2.4.

16.5.11 Alarms and safeguards for electric propulsion equipment are indicated in Table 1.16.1.

Table 1.16.1 Electric propulsion equipment: Alarms and safeguards

Item	Alarm	Note
Electric propulsion equipment ventilation and cooling medium temperature	High	*See* 16.1.2 and 16.3.9
Electric propulsion transformer winding temperature	High	*See* 9.1.11
Electric propulsion generator excitation	Overload	*See* 16.5.6
Electric propulsion generators and motors winding temperature	High	*See* 16.1.3
Electric propulsion generator and motor lubricating oil temperature	High	*See* 8.1.11
Electric propulsion generator and motor lubricating oil supply pressure	Low	*See* 8.1.12
Power limitation	—	Indication, *see* 16.4.8 and 16.4.9

~~15.5~~ 16.6 Instruments

~~15.5.1~~ 16.6.1 The main control station is to be provided with indicating instruments or other means of continuously monitoring the following:

(a) a.c. systems
   (i) The line current and excitation current of each generator, ~~and~~ propulsion motor and propulsion transformer primary; and for each generator, the voltage, power and frequency.
   (ii) The winding, bearings and cooling system temperature of each generator, propulsion transformer and propulsion motor.
(b) d.c. systems
   (i) The armature voltage and current for each generator and propulsion motor and the current in each excitation circuit.

~~15.5.2~~ 16.6.2 Each control station is to be provided with instruments to indicate:

(a) propeller speed;
(b) direction of rotation for a fixed pitch propeller or pitch position for a controllable pitch propeller;
(c) visual indication of power limitation~~.~~; and
(d) the station in control.

■ *Section ~~16~~ 17*
Fire safety systems

~~16.1~~ 17.1 Fire detection and alarm systems

~~*16.1.1* Fire detection and alarm systems are to be provided with an emergency source of electrical power required by 3.2 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main fire control panel are to be provided. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.13 and 1.14.~~

17.1.1 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by 3.2, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with 11.6.4.

17.1.2 Automatic changeover facilities in accordance with 5.3.4 are to be located in, or adjacent to, the main fire control panel. Power supply changeover is to be achieved without adverse affect. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.14 and 1.16.

17.1.3 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

17.1.4 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and fire alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

Existing paragraphs 16.1.2 *to* 16.1.15 *have been renumbered* 17.1.5 *to* 17.1.18.

Existing sub-Sections 16.2 *to* 16.5 *have been renumbered* 17.2 *to* 17.5.

~~16.6~~ 17.6 Fire safety stops

Existing paragraphs 16.6.1 *to* 16.6.3 *have been renumbered* 17.6.1 *to* 17.6.3.

~~16.6.4~~ 17.6.4 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire. Consideration may be given to relaxing this requirement for supplies to equipment not used for heating or cooking (e.g., alarm and clock systems) that do not present an electrical shock risk to fire-fighting personnel.

Existing paragraphs 16.6.5 *and* 16.6.6 *have been renumbered* 17.6.5 *and* 17.6.6.

Existing sub-Sections 16.7 *to* 16.9 *have been renumbered* 17.7 *to* 17.9.

Existing Sections 17 *to* 19 *have been renumbered* 18 *to* 20.

■ *Section ~~20~~ 21*
Testing and trials

Existing sub-Section 20.1 *has been renumbered* 21.1.

Existing Table 1.20.1 *has been renumbered* Table 1.21.1.

Existing Table 1.20.2 *has been renumbered* Table 1.21.2.

~~20.2~~ 21.2 Trials

Existing paragraphs 20.2.1 *to* 20.2.3 *have been renumbered* 21.2.1 *to* 21.2.3.

~~20.2.4~~ 21.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;

(b) temperature of joint, connections, circuit-breakers and fuses;

(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;

(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;

(e) voltage drop at the worst case condition;

(f) harmonic distortion of the voltage waveform, where declared;

~~(e)~~(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;

~~(f)~~ (h) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory;

~~(g)~~(j) propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed, is to be demonstrated at the sea trial, *see also* Pt 1, ~~Ch 2,16.3.7.~~ Ch 2,17.3.7;

(k) operation of power management for electric propulsion.

21.2.5 Measurements are to be taken as part of the trials specified in 21.2.4(c), (d), (e) and (f) to verify that the installation will provide a quality of power supply in accordance with the values listed in 1.7.

~~20.2.5~~ 21.2.6 In addition to 21.2.5, ~~Unless~~ unless it has been satisfactorily shown by the design verification and validation process required by 1.8.5 that the power supply quality complies with the requirements of the defined standard, then compliance is to be demonstrated by measurements taken at the switchboards/section-boards used to supply sensitive military loads, *see* 1.8.1.

Existing paragraphs 20.2.6 *and* 20.2.7 *have been renumbered* 21.2.7 *and* 21.2.8.

Existing sub-Sections 20.3 *and* 20.4 *has been renumbered* 21.3 *and* 21.4.

Existing Section 21 *has been renumbered* 22.

Volume 2, Part 11, Chapter 1

Made and Fresh Water Systems

Effective date 1 January 2012

■ *Section 2*

System construction and installation

2.3 Piping and equipment – Selection and installation

2.3.1 Pressurised tanks are to be in accordance with ~~a recognised and appropriate code~~ the requirements of Pt 8, Ch 2 and satisfy the Naval Authority's revalidation system for such items where applicable.

Volume 2, Part 11, Chapter 2

Heating, Ventilation and Cooling Arrangements

Effective date 1 January 2011

■ *Section 2*

Construction and installation

2.1 Materials

2.1.3 Where trunking is fitted in lengths and required to be joined together, joining arrangements are to be in accordance with the requirements of the trunk manufacturer.

~~*2.1.3*~~ *2.1.4* Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to the restrictions in Pt 7, Ch 1.

~~*2.1.4*~~ *2.1.5* Where applicable, the materials are to comply with the requirements of Pt 7, Ch 1.

■ *Section 3*

System arrangements

3.2 Magazines, stores and spaces containing flammable liquids and gases/vapours

3.2.2 Systems serving compartments containing flammable stores (e.g. paint stores) or potentially explosive gases (including battery charging rooms, oxygen bottle stores and magazines) are to be fitted with flameproof gauzes and isolating valves in these branches. The systems serving such compartments are to be independent of those supplying other spaces. Fans supplying and extracting air to/from such compartments are to be spark resistant as a minimum, *see* Vol 2, Pt 7, Ch 4,3.3. Exhausts are to be led to atmosphere away from other outlets, i.e. fuel tank vents.

Volume 3, Part 2, Chapter 3

Provision Refrigeration

CORRIGENDUM

■ *Section 3*
Refrigerating machinery and refrigerant storage compartment arrangements

3.4 Pressure test after installation on board ship

3.4.3 Where pneumatic tests are prohibited by relevant authorities, the tests required by 3.3.1 and 3.3.2 may be omitted provided non-destructive examination has been carried out by an approved operator to the satisfaction of LR and in accordance with the requirements of Vol 2, Pt 1, ~~Ch 3,7~~ Ch 3,6.

Volume 3, Part 3, Chapter 1

General Requirements

Effective date 1 January 2012

■ *Section 1*
Scope

1.4 Topics within this Part of the Rules

1.4.8 **Double Star Endorsements (★★)**. All Class Notations that are available in Chapters 2, 3 and 4 of this Part of the Rules will be eligible for a ‘Double Star’ endorsement where the arrangements on board are in accordance with stated ~~National Administration~~ Naval Authority requirements and *ANEP-77 NATO Naval Ship Code* (NSC). This does not necessarily denote automatic endorsement by the ~~National Administration~~ Naval Authority.

Section numbering in brackets reflects any Section renumbering necessitated by any of the Notices that update the current version of the Rules for Naval Ships.

Volume 1, Part 4, Chapter 1

2.2.4	*Reference* Pt 1, Ch 2,3.9.9 *now reads* Pt 1, Ch 2,3.9.7.
6.1.1	*Reference* Pt 1, Ch 2,1.1.12 *now reads* Pt 1, Ch 2,1.1.13.
6.8.1	*Reference* Pt 10, Ch 1,13 *now reads* Pt 10, Ch 1,14.

Volume 1, Part 6, Chapter 4

4.4.1	*References* 4.1.13 *now read* 4.1.8
4.5.1	*Reference* 4.1.13 *now reads* 4.1.8
4.6.1	*Reference* 4.1.13 *now reads* 4.1.8

Volume 2, Part 1, Chapter 2

3.3.16	*Reference* Vol 2, Pt 10, Ch 1, Section 20 *now reads* Vol 2, Pt 10, Ch 1, Section 21.
4.15.1	*Reference* Vol 2, Pt 9, Ch 1, Section 2.12 *now reads* Vol 2, Pt 9, Ch 1, Section 2.13.
5.11.7	*Reference* Pt 10, Ch 1,16.9.1 *now reads* Pt 10, Ch 1,17.9.1.

Volume 2, Part 2, Chapter 1

2.1.6 ***(2.1.5)***	*Reference* 7.1 *now reads* 7.11.
7.1.2 ***(7.11.2)***	*Reference* 7.1.1 *now reads* 7.11.1.
7.2.1 ***(7.1.2)***	*Reference* 7.1 *now reads* 7.11.
7.2.1 ***(7.1.2)***	*Reference* 7.3 *now reads* 7.12.
7.2.5 ***(7.1.6)***	*Reference* 7.2.1 *now reads* 7.1.2.
7.5.1 ***(7.14.1)***	*Reference* 7.3 *now reads* 7.12.
7.5.4 ***(7.14.4)***	*Reference* 7.5.1 *now reads* 7.14.1.
7.5.4 ***(7.14.4)***	*Reference* 7.5.3 *now reads* 7.14.3.
7.6.4 ***(7.15.4)***	*Reference* 15.5 *now reads* 15.7.
7.6.6 ***(7.15.6)***	*Reference* 7.6.2 *now reads* 7.15.2.
7.6.6 ***(7.15.6)***	*Reference* 7.6.3 *now reads* 7.15.3.
9.7.6 ***(9.7.7)***	*Reference* 7.5 *now reads* 7.14.
Table 1.9.1(a)	*Reference* 9.7.7 *now reads* 9.7.8 (twice).
11.5.4 (***11.5.5***)	*Reference* 11.5.3 *now reads* 11.5.4. *Reference* 11.5.10 *now reads* 11.5.11. *Reference* 11.5.11 *now reads* 11.5.12.
11.5.5 (***11.5.6***)	*Reference* 11.5.3 *now reads* 11.5.4.
11.5.8 (***11.5.9***)	*Reference* 11.5.7 *now reads* 11.5.8.
15.5.4 (***15.7.4***)	*Reference* Pt 10, Ch 1,9.3 *now reads* Pt 10, Ch 1,10.3.
15.1.1	*Reference* 15.5 *now reads* 15.7.
15.5.3 (***15.7.3***)	*Reference* 15.5.4 *now reads* 15.7.4.
15.5.3 (***15.7.3***)	*Reference* 15.5.5 *now reads* 15.7.5.

Volume 2, Part 4, Chapter 3

7.2.1	*Reference* Pt 10, Ch 1,15.2.5 *now reads* Pt 10, Ch 1,16.3.5.
7.4.1	*Reference* Pt 10, Ch 1,8.4.2 and 8.4.7 *now reads* Pt 10, Ch 1,9.4.2 and 9.4.7.

Volume 2, Part 4, Chapter 4

1.1.8	*Reference* Pt 10, Ch 1,20.2 *now reads* Pt 10, Ch 1,21.2.
6.7.2	*Reference* Pt 10, Ch 1,8.6.1 *now reads* Pt 10, Ch 1,9.6.1.
8.1.5	*Reference* Pt 10, Ch 1,15.3.7 *now reads* Pt 10, Ch 1,16.4.7.
8.1.6(b)	*Reference* Pt 9, Ch 1,2.12 *now reads* Pt 9, Ch 1,2.13.
8.1.7	*Reference* Pt 9, Ch 1,2.13 *now reads* Pt 9, Ch 1,2.14.

Volume 2, Part 7, Chapter 1

8.2.3	*Reference* Pt 2, Ch 1,7.4.4 *now reads* Pt 2, Ch 1,7.13.4.
11.8.2	*Reference* Pt 10, Ch 1,20.2.3 *now reads* Pt 10, Ch 1,21.2.3.

Volume 2, Part 7, Chapter 3

3.3.2	*Reference* Pt 2, Ch 1,7.1 *now reads* Pt 2, Ch 1,7.11.
Table 3.9.1	*Reference* 3.1.10 *now reads* 3.1.12. *Reference* 3.1.7 *now reads* 3.1.9. *Reference* 3.1.9 *now reads* 3.1.11. *Reference* 3.1.10 *now reads* 3.1.12.
9.3.5	*Reference* Ch 3,3.1.7 *now reads* Ch 3,3.1.9.
9.3.7	*Reference* Ch 3,3.1.8 *now reads* Ch 3,3.1.10.
11.1.11	*Reference* Pt 10, Ch 1,8.6.1 *now reads* Pt 10, Ch 1,9.6.1. *Reference* Pt 10, Ch 1,9.1.10 and 9.1.11 *now reads* Pt 10, Ch 1,10.1.10 and 10.1.11. *Reference* Pt 10, Ch 1,9.2.4 to 9.2.7 *now reads* Pt 10, Ch 1,10.2.4 to 10.2.7.

Volume 2, Part 7, Chapter 4

2.1.5	*Reference* 2.5.1 *now reads* 2.6.1.
2.2.1 (***2.3.1***)	*Reference* 2.2.2 *to* 2.2.14 *now reads* 2.3.2 *to* 2.3.14.
2.4.2 (***2.5.2***)	*Reference* 2.3.3 *now reads* 2.4.3.
2.5.1 (***2.6.1***)	*Reference* 2.3.2 *now reads* 2.4.2.

Cross-references

Volume 2, Part 8, Chapter 1

18.2.7	*Reference* Pt 7, Ch 3,3.1.7 *now reads* Pt 7, Ch 3,3.1.9.
18.2.9	*Reference* Pt 7, Ch 3,3.1.8 *now reads* Pt 7, Ch 3,3.1.10.
Table 1.18.1	*Reference* Pt 7, Ch 3,3.1.7 *now reads* Pt 7, Ch 3,3.1.9.
Table 1.18.1	*Reference* Pt 7, Ch 3,3.1.9 *now reads* Pt 7, Ch 3,3.1.11.
Table 1.18.1	*Reference* Pt 7, Ch 3,3.1.10 *now reads* Pt 7, Ch 3,3.1.12.

Volume 2, Part 9, Chapter 1

1.2.1	*Reference* 1.2.7 *now reads* 1.2.8.
1.2.3	*Reference* 6.4.1 *now reads* 6.5.1.
1.2.5	*Reference* 2.12.6 *now reads* 2.13.6. *Reference* 2.12.3 *now reads* 2.13.3. *Reference* 2.13.2 *now reads* 2.14.2. *Reference* 2.13.5 *now reads* 2.14.5.
1.2.9 ***(1.2.10)***	*Reference* Pt 10, Ch 1,10 *now reads* Pt 10, Ch 1,11.
2.5.7	*Reference* 2.13.2 *now reads* 2.14.2.
2.8.6	*Reference* Pt 10, Ch 1,16.1 *now reads* Pt 10, Ch 1,17.1.
2.9.2	*Reference* Pt 10, Ch 1,16.3.4 *now reads* Pt 10, Ch 1,17.3.4.
2.9.3	*Reference* Pt 10, Ch 1,16.3.12 *now reads* Pt 10, Ch 1,17.3.12.
2.9.4	*Reference* Pt 10, Ch 1,16.3.5 *now reads* Pt 10, Ch 1,17.3.5.
2.10.1	*References* 2.12 and 2.13 *now reads* 2.13 and 2.14.
2.10.2	*Reference* 2.13 *now reads* 2.14.
2.10.5	*Reference* 2.12.3 *now reads* 2.13.3.
2.10.6	*Reference* 2.12.2 and/or 2.12.8 *now reads* 2.13.2 and/or 2.13.8.
2.10.9	*Reference* 2.12.6 *now reads* 2.13.6.
2.10.12	*Reference* 11.7 *now reads* 12.7.
2.11.8 ***(2.11.9)***	*Reference* Pt 10, Ch 1,10 *now reads* Pt 10, Ch 1,11.
2.12.1 ***(2.13.1)***	*References* 2.12.2 to 2.12.10 *now reads* 2.13.2 *to* 2.13.10.
2.13.1 ***(2.14.1)***	*References* 2.13.2 to 2.13.7 *now reads* 2.14.2 *to* 2.14.7.
4.1.1	*Reference* 2.12 *now reads* 2.13.
5.1.2	*Reference* 2.13.5 *now reads* 2.14.5.
5.2.1	*Reference* 2.13 *now reads* 2.14.
5.2.3	*Reference* 2.12.8 *now reads* 2.13.8.

Volume 2, Part 10, Chapter 1

1.2.1	*Reference* 1.2.15 *now reads* 1.2.16. *Reference* 1.2.16 to 1.2.21 *now reads* 1.2.17 to 1.2.22.
1.2.4	*Reference* 10.6.2 *now reads* 11.6.2.
1.2.6	*Reference* 13.2 *now reads* 14.2.
1.2.6 ***(1.2.7)***	*Reference* 13.3 *now reads* 14.3.
1.2.9 ***(1.2.10)***	*Reference* 16.3.9 *now reads* 17.3.9.
1.2.9 ***(1.2.10)***	*Reference* 16.3.10 *now reads* 17.3.10.
1.2.12 ***(1.2.13)***	*Reference* 11.5 *now reads* 12.5.
1.2.13 ***(1.2.14)***	*Reference* 11.7 *now reads* 12.7.
1.2.14 ***(1.2.15)***	*Reference* 10.8 *now reads* 11.8.
1.2.15 ***(1.2.16)***	*Reference* 10.8.10 *now reads* 11.8.10.
1.3.3	*Reference* 10.1.3 *now reads* 11.1.3.
1.4.5	*Reference* 11.5.9 *now reads* 12.5.9.
1.4.5	*Reference* 11.3 *now reads* 12.3.
1.4.5	*Reference* 11.4 *now reads* 12.4.
1.4.6	*Reference* 14.5 *now reads* 15.5.
1.4.6	*Reference* 14.5.5 *now reads* 15.5.5.
1.4.6	*Reference* 14.5.6 *now reads* 15.5.6.
1.5.11	*Reference* Pt 2, Ch 1,7.6 *now reads* Pt 2, Ch 1,7.15.
1.8.5	*Reference* 8.4 *now reads* 9.4.
1.8.6	*Reference* 8.4 *now reads* 9.4.
1.8.7	*Reference* 20.2.5 *now reads* 21.2.5.
1.11.3(d)	*Section* 13 *now reads Section* 14.
1.11.7	*Reference* 10.5 *now reads* 11.5.
1.12.4	*Reference* 13.9.3 *now reads* 14.9.3.
1.14.3	*Reference* 1.16 *now reads* 1.17.
1.14.4	*Reference* 1.16 *now reads* 1.17.
1.16.1 ***(1.17.1)***	*Reference* 17.4.3 *now reads* 18.4.3. *Reference* 16.6 *now reads* 17.6.
1.16.2 ***(1.17.2)***	*Reference* 1.16.1 *now reads* 1.17.1. *Reference* 10.5.3 *now reads* 11.5.3.
1.16.3 ***(1.17.3)***	*Reference* 1.16.1 *now reads* 1.17.1. *Reference* 10.5.3 *now reads* 11.5.3.
1.16.4 ***(1.17.4)***	*Reference* 1.16.1 *now reads* 1.17.1.
1.17.1 ***(1.18.1)***	*Section* 19 *now reads Section* 20.
1.19.2 ***(1.20.2)***	*Reference* 1.19.1 *now reads* 1.20.1
2.2.1(a)	*Reference* 15.2.5 *now reads* 16.3.5.
3.3.1	*Reference* Pt 2, Ch 1,7.6 *now reads* Pt 2, Ch 1,7.15.
5.7.4	*Section* 17 *now reads Section* 18.
5.7.6	*Section* 13 *now reads Section* 14.
6.1.7	*Reference* 11.3.5 *now reads* 12.3.5.
6.9.3	*Reference* 15.2 *now reads* 16.3.
7.18.2	*Section* 20 *now reads Section* 21.
8.1.2 ***(9.1.2)***	*Reference* 8.8 *now reads* 9.8.
8.1.9 ***(9.1.9)***	*Reference* 15.1.3 *now reads* 16.1.3.
8.2.1 ***(9.2.1)***	*Reference* 8.3 *now reads* 9.3 (twice).
8.8.3 ***(9.8.3)***	*Section* 20 *now reads Section* 21.
9.1.1 ***(10.1.1)***	*Reference* 9.1.2 to 9.1.12 *now reads* 10.1.2 to 10.1.13.
9.1.12 ***(10.1.13)***	*Reference* 9.1.9 *now reads* 10.1.9.
9.2.1 ***(10.2.1)***	*Reference* 9.2.2 to 9.2.17 *now reads* 10.2.2 to 10.2.17.
9.2.18 ***(10.2.18)***	*Reference* 20.1 *now reads* 21.1.
9.3.1 ***(10.3.1)***	*Reference* 9.1 to 9.2 and Section 11 *now reads* 10.1 to 10.2 and Section 12.
9.3.8 ***(10.3.8)***	*Reference* 11.3.5 *now reads* 12.3.5. *Reference* 11.5.10 *now reads* 12.5.10.
9.3.12 ***(10.3.12)***	*Reference* 20.1 *now reads* 21.1.
10.1.1 ***(11.1.1)***	*Reference* 10.17 *now reads* 11.17. *Reference* 10.1 to 10.15 *now reads* 11.1 *to* 11.15.
10.1.2 ***(11.1.2)***	*Reference* Table 1.10.1 *now reads* Table 1.11.1.
10.1.4 ***(11.1.4)***	*Reference* 10.1.2 *now reads* 11.1.2.
10.2.1(b) ***(11.2.1)***	*Section* 20 *now reads Section* 21.
10.2.2 ***(11.2.2)***	*Reference* 10.1.2 *now reads* 11.1.2.
10.4.3 ***(11.4.3)***	*Reference* Table 1.10.2 *now reads* Table 1.11.2. *Reference* 10.1.2 *now reads* 11.1.2.
10.5.1 ***(11.5.1)***	*Reference* 10.8.10 *now reads* 11.8.10.
10.5.2 ***(11.5.2)***	*Reference* 10.5.1 *now reads* 11.5.1.

10.5.5 ***(11.5.5)***	*Reference* 10.8.7 *now reads* 11.8.7. *Reference* 10.8.8 *now reads* 11.8.8.
10.6.1 ***(11.6.1)***	*Reference* 10.7 *now reads* 11.7.
10.6.5 ***(11.6.5)***	*Reference* 1.12.8 *now reads* 1.12.7.
10.6.6 ***(11.6.6)***	*Reference* 10.7.4 *now reads* 11.7.4.
10.7.1 ***(11.7.1)***	*Reference* 10.7.2 to 10.7.5 *now reads* 11.7.2 to 11.7.5.
10.7.3 ***(11.7.3)***	*Reference* Table 1.10.3 *now reads* Table 1.11.3. *Reference* Table 1.10.5 *now reads* Table 1.11.5.
10.8.2 ***(11.8.2)***	*Reference* Table 1.10.6 *now reads* Table 1.11.6.
10.8.17 ***(11.8.17)***	*Reference* 10.9 *now reads* 11.9.
10.8.18 ***(11.8.18)***	*Reference* 10.10 *now reads* 11.10.
10.8.19 ***(11.8.19)***	*Reference* 10.11 *now reads* 11.11.
10.8.20 ***(11.8.20)***	*Reference* 10.12 *now reads* 11.12.
10.8.21 ***(11.8.21)***	*Reference* 10.14 *now reads* 11.14. *Reference* 10.5.7 *now reads* 11.5.7.
10.10.1 ***(11.10.1)***	*Reference* 10.8.4 *now reads* 11.8.4.
10.10.3 ***(11.10.3)***	*Reference* Table 1.10.7 *now reads* Table 1.11.7.
10.10.4 ***(11.10.4)***	*Reference* Table 1.10.7 *now reads* Table 1.11.7.
10.12.3 ***(11.12.3)***	*Reference* 10.8.2 *now reads* 11.8.2.
10.13.1 ***(11.13.1)***	*Reference* 10.8.14(b) *now reads* 11.8.14(b).
10.16.3 ***(11.16.3)***	*Reference* 10.5.3 *now reads* 11.5.3.
10.17.1 ***(11.17.1)***	*Reference* 10.17.2 *now reads* 11.17.2.
10.18.1 ***(11.18.1)***	*Reference* Table 1.10.8 *now reads* Table 1.11.8. *Reference* Table 1.10.9 *now reads* Table 1.11.9.
11.3.2 ***(12.3.2)***	*Reference* 11.3.1 *now reads* 12.3.1.
11.3.4 ***(12.3.4)***	*Reference* 11.3.1 *now reads* 12.3.1. *Reference* 11.3.2 *now reads* 12.3.2. *Reference* 11.3.3 *now reads* 12.3.3.
11.3.5 ***(12.3.5)***	*Reference* 11.5.10 *now reads* 12.5.10. *Reference* 11.6.5 *now reads* 12.6.5. *Reference* 11.6.4 *now reads* 12.6.4.
11.3.9 ***(12.3.9)***	*Reference* 11.3.1 *now reads* 12.3.1.
11.5.4 ***(12.5.4)***	*Reference* 11.5.9 *now reads* 12.5.9.
11.5.5 ***(12.5.5)***	*Reference* 11.3.2 *now reads* 12.3.2. *Reference* 11.3.3 *now reads* 12.3.3. *Reference* 11.3.5 *now reads* 12.3.5.
11.5.10 ***(12.5.10)***	*Reference* 11.5.9 *now reads* 12.5.9.
12.3.1 ***(13.3.1)***	*Reference* Table 1.12.1 *now reads* Table 1.13.1.
12.4.1 ***(13.4.1)***	*Reference* Table 1.12.1 *now reads* Table 1.13.1.
13.1.4 ***(14.1.4)***	*Reference* 13.2 *now reads* 14.2. *Reference* 13.3 *now reads* 14.3.
13.1.5 ***(14.1.5)***	Section 11 *now reads* Section 12.
13.2.1 ***(14.2.1)***	*Reference* 13.2.4 *now reads* 14.2.4. *Reference* 13.2.5 *now reads* 14.2.5. *Reference* 13.2.6 *now reads* 14.2.6.
13.2.2 ***(14.2.2)***	*Reference* 13.5 *now reads* 14.5.
13.2.3 ***(14.2.3)***	*Reference* 13.2.4 *now reads* 14.2.4. *Reference* 13.2.5 *now reads* 14.2.5.
13.3.1 ***(14.3.1)***	*Reference* 13.5.3 *now reads* 14.5.3.
13.3.3 ***(14.3.3)***	*Reference* 13.5.3 *now reads* 14.5.3.
13.3.4(e) ***(14.3.4(e))***	*Reference* 13.2.4 *now reads* 14.2.4. *Reference* 13.2.5 *now reads* 14.2.5. *Reference* 13.2.6 *now reads* 14.2.6.
13.5.5(a) ***(14.5.5(a))***	*Reference* 13.5.4 (a) & (b) *now reads* 14.5.4 (a) & (b).
13.5.5(b) ***(14.5.5(b))***	*Reference* 13.5.4 (b) & (e) *now reads* 14.5.4 (b) & (e).
13.5.6(a) ***(14.5.6(a))***	*Reference* 13.5.4 (d) *now reads* 14.5.4 (d).
13.5.6(b) ***(14.5.6(b))***	*Reference* 13.5.4 (a) *now reads* 14.5.4 (a).
13.5.6(c) ***(14.5.6(c))***	*Reference* 13.5.4 (b) & (e) *now reads* 14.5.4 (b) & (e).
13.5.6(d) ***(14.5.6(d))***	*Reference* 13.5.4 (b) & (e) *now reads* 14.5.4 (b) & (e).
13.5.6(d) ***(14.5.6(d))***	*Reference* 13.7 *now reads* 14.7.
13.5.6(e) ***(14.5.6(e))***	*Reference* 13.5.4 (b) *now reads* 14.5.4 (b).
13.5.6(f) ***(14.5.6(f))***	*Reference* 13.5.4 (e) & (f) *now reads* 14.5.4 (e) & (f).
13.5.6(g) ***(14.5.6(g))***	*Reference* 13.5.4 (a) *now reads* 14.5.4 (a).
13.5.7(b) ***(14.5.7(b))***	*Reference* 13.5.6 (d) to (h) *now reads* 14.5.6 (d) to (h).
13.7.1 ***(14.7.1)***	*Reference* 13.5.5 (b) *now reads* 14.5.5 (b). *Reference* 13.5.6 (e) & (j) *now reads* 14.5.6 (e) & (j). *Reference* 13.5.7(d) *now reads* 14.5.7(d).
13.5.7(c) ***(14.5.7(c))***	*Reference* 13.6.4 (a) & (c) *now reads* 14.5.6 (a) & (c).
13.9.3 ***(14.9.3)***	*Section* 10 *now reads Section* 11.
14.1.1 ***(15.1.1)***	*Reference* 14.1.2 to 14.1.7 *now reads* 15.1.2 to 15.1.7.
14.1.6 ***(15.1.6)***	*Reference* 14.1.5 *now reads* 15.1.5.
14.5.6 ***(15.5.6)***	*Reference* 14.5.5 *now reads* 15.5.5.
14.5.7 ***(15.5.7)***	*Reference* 14.5.1 *now reads* 15.5.1.
14.5.8 ***(15.5.8)***	*Reference* 14.5.4 *now reads* 15.5.4.
14.5.8 ***(15.5.8)***	*Reference* 14.5.5 *now reads* 15.5.5.
14.5.9 ***(15.5.9)***	*Reference* 14.5.1 *now reads* 15.5.1.
15.1.3 ***(16.1.3)***	*Reference* 8.1.9 *now reads* 9.1.9.
16.1.3 ***(17.1.6)***	*Reference* 16.1.4 *now reads* 17.1.7. *Reference* 16.1.13 *now reads* 17.1.16.
16.3.5 ***(17.3.5)***	*Reference* 16.3.6 to 16.3.10 *now reads* 17.3.6 to 17.3.10.
16.3.9 ***(17.3.9)***	*Reference* 16.3.8 *now reads* 17.3.8.
16.3.9(a) ***(17.3.9(a))***	*Reference* 16.3.6 *now reads* 17.3.6. *Reference* 16.3.7 *now reads* 17.3.7.
16.3.10 ***(17.3.10)***	*Reference* 16.3.9 *now reads* 17.3.9.
16.3.11 ***(17.3.11)***	*Reference* 16.3.12 to 16.3.14 *now reads* 17.3.12 to 17.3.14.
16.6.3 ***(17.6.3)***	*Reference* 16.6.2 *now reads* 17.6.2.
16.6.5	*Reference* 10.5.3 *now reads* 11.5.3.
17.1.3 ***(18.1.3)***	*Reference* 17.4 *now reads* 18.4.
17.2.6 ***(18.2.6)***	*Reference* 20.2 *now reads* 21.2.
17.3.9 ***(18.3.9)***	*Reference* 17.2 *now reads* 18.2.
17.3.11 ***(18.3.11)***	*Reference* 20.2 *now reads* 21.2.
17.4.3	*Reference* 10.5.3 *now reads* 11.5.3.
18.2.2 ***(19.2.2)***	*Reference* 18.1 *now reads* 19.1.
20.1.2 ***(21.1.2)***	*Reference* Table 1.20.1 *now reads* Table 1.21.1.
20.1.4 ***(21.1.2)***	*Reference* Table 1.20.2 *now reads* Table 1.21.2.
20.2.2 ***(21.2.2)***	*Reference* Table 1.20.2 *now reads* Table 1.21.2.
20.2.1 ***(21.2.1)***	*Reference* 20.2.2 to 20.2.4 *now reads* 21.2.2 to 21.2.4.
20.3.1 ***(21.3.1)***	*Reference* 20.2.2 *now reads* 21.2.2.
20.3.3 ***(21.3.3)***	*Reference* 20.2.2 *now reads* 21.2.2.

Cross-references

Volume 2, Part 11, Chapter 2

1.2.5	*Reference* Pt 10, Ch 1,13.10 *now reads* Pt 10, Ch 1,14,10.
1.2.8	*Reference* Pt 10, Ch 1,11.5 *now reads* Pt 10, Ch 1,12.5.

Volume 3, Part 1, Chapter 1

1.1.1	*Reference* Vol 1, Pt 1, Ch 2,3.9.14 *now reads* Vol 1, Pt 1, Ch 2,3.9.13.
2.1.1	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
2.2.2	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
2.3.2	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
2.3.4	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
2.4.2	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
2.5.3	*Reference* Vol 1, Pt 3, Ch 2,3.9.14 *now reads* Vol 1, Pt 3, Ch 2,3.9.13.
3.16.1	*Reference* Vol 2, Pt 2, Ch 1,7.1 to 7.5 *now reads* Vol 2, Pt 2, Ch 1,7.11, 7.1, 7.12, 7.13 and 7.14.

Volume 3, Part 1, Chapter 5

6.1.11	*Reference* Vol 2, Pt 10, Ch 1,13 *now reads* Vol 2, Pt 10, Ch 1,14.

Volume 3, Part 2, Chapter 1

2.4.1	*Reference* 17.3 *now reads* 18.3.

Volume 3, Part 2, Chapter 3

3.4.3	*Reference* Ch 3,7 *now reads* Ch 3,6.

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